

**SURVEY OF SOIL MAP UNIT SENSITIVITY TO
ACID DEPOSITION IN THE SIERRA NEVADA, CALIFORNIA**

**Executive Summary
Contract No. A733-037**

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FEBRUARY 1990

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EXECUTIVE SUMMARY

BACKGROUND

An important statutory goal of the Air Resources Board is to determine where acid deposition is occurring or might be expected to occur in amounts which could be adverse to the environment. The Air Resources Board has funded a number of projects through the Integrated Watershed Study (IWS) at Emerald Lake, Sequoia National Park, to determine the impacts of terrestrial and aquatic acidification on high elevation montane ecosystems. Future research will attempt to place the results of the IWS in a regional context. Soil bodies are suitable for grouping ecological systems with respect to their response to acid deposition and therefore, may be used to extend the IWS findings to wide geographic areas.

This project has two objectives. The first objective is to use taxonomic soil survey information to rank soil bodies in terms of physical and chemical characteristics which may influence watershed response to acid deposition. The second objective is to create a map of soil bodies which shows their geographic distribution and relative sensitivity, and also provides base-line information to compare soils characteristics in different watersheds.

APPROACH

The study area encompasses the frigid and cooler, cryic soil temperature regimes of the western slope of the Sierra Nevada. The northern boundary is the middle fork of the Yuba River; the southern boundary occurs within the Sequoia National Forest. Sensitivity rankings are limited to areas that have been taxonomically surveyed or that were surveyed as part of this project: sensitivity rankings are provided for approximately 2,116,448 acres.

A computer program was developed to simulate changes in soil chemistry induced by acid deposition. Soil samples collected from throughout the study area were used to calibrate the model and as model input. Individual soils were ranked according to their simulated response to acidification with 0.3 kmols H⁺/ha/yr over 50 years. In addition to the response ranking of individual soil types, slope and hydrologic soil group (an index of runoff potential), were used to rank the sensitivity response of aggregations of individual soil types (e.g., soil map units). In this study, map unit sensitivity is defined as the relative capacity of study area soil map units to attenuate acid inputs.

Soil map unit boundaries were digitized from published reports. The map was plotted at 1:62,500 scale. Map unit delineations were hatched to indicate the sensitivity class ranking. The map is registered to identical scale USGS 15-minute quadrangles; portions of forty-five 18-inch x 24-inch sheets are required for coverage of the entire study area. The soil survey report for areas within the national parks mapped under this effort, and the database describing soil characteristics in the study area, are submitted as Appendixes A and B, respectively.

RESULTS AND CONCLUSIONS

Approximately 527,564 acres, or 24.9 percent of the study area, are considered least sensitive. Eighteen percent of the area, approximately 380,677 acres, are moderately sensitive. Almost 56 percent of the study area, or 1,183,601 acres, are most sensitive. Water occupies 24,586 acres, or approximately 1.2 percent of the study area.

Typically the least sensitive soil map units contain non-sensitive soils more than forty inches deep. Least sensitive soil map units are level or gently sloping landscapes and include little rock outcrop or other miscellaneous land types.

Moderately sensitive soil map units contain shallow, non-sensitive soils on steep slopes and sensitive soils on slopes less than 35 percent. Highly sensitive soil map units contain sensitive soils on slopes steeper than 30 percent. Also, map units that contain 50 percent miscellaneous land type are considered highly sensitive, regardless of other characteristics.

Effective soil depth is an important determinant of soil response within the study area. Initial base saturation, pH, parent material, cation exchange capacity, and organic carbon content were somewhat less influential. The relative importance of soil characteristics in determining response varied according to soil horizon.

RECOMMENDATIONS

- 1) The soil survey (i.e., map sheets and database tables) should be used as a tool for comparing soil characteristics of watersheds throughout the 2-million acre study area. Understanding watershed similarities and differences will assist the ARB in selecting representative locations for future study and monitoring of a variety of environmental characteristics in addition to soils.
- 2) Soil survey information should be used to:
 - o Refine the USGS watershed model;
 - o Refine regional lake acidification models; and,
 - o Develop, calibrate and test a mechanistic watershed model.
- 3) Soil survey information should be used as baseline data to monitor changes in edaphic factors in forested areas of California.

- 4) The graphics element of this project should be linked to the database element to create a true geographic information system, (GIS). The GIS could then be used by other researchers to compare environmental characteristics and to simulate the ecological response to acid deposition over large areas.
- 5) Additional soil samples, presently archived, should be analyzed. The chemical data should be used to refine the sensitivity model and to improve the integrity of the baseline data.
- 6) An effort should be made to quantify the importance of the litter layer and the effect of fire in determining sensitivity.
- 7) Soil survey data is widely used in wildland resource management. The Air Resources Board should establish cooperative agreements with land management agencies to share the cost of assembling soil survey information in a consistent format throughout the forested portions of California.

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ABSTRACT

A method for classifying soil map units on the basis of relative response to acid deposition is described. Study area boundaries are the crest of the Sierra Nevada west to the interface of the mesic and frigid soil temperature regimes; and from 35°45'00" north latitude to 39°31'44" north latitude. The Emerald Lake Integrated Watershed Study Area and seventy-eight sampled Sierran lakes are included in the 2,116,448 acre study area.

A computer program was developed which calculates changes in soil base saturation and pH given soil chemical parameters and an acidification regime. A rate of 0.3 kmol H⁺/hectare/year was imposed on soils for 50 years to determine relative capacities to maintain base saturation and pH.

One hundred sixty-seven soil samples from forty-three modal soil profiles were analyzed for relevant chemical characteristics. Extrapolations were made on the basis of soil taxonomic similarities to represent the chemical composition of the one hundred fifty taxonomic components which occur in the study area.

Soil chemical data and map unit data were organized in a relational database. Taxonomic units were ranked according to the projected base saturation after fifty years of deposition. This ranking was combined with soil hydrologic grouping and map unit slope to rank soil map units in terms of their relative abilities to attenuate additions of strong mineral acids. Map units on less steep slopes containing high percentages of soils with low runoff characteristics and high buffering capacities are termed least sensitive. Other soils are termed moderately sensitive or most sensitive.

The distribution and relative sensitivities of soil map units are presented in a 1:62,500 scale map registered to USGS 15-minute quadrangles. Forty-five 18-inch by 24-inch sheets are required for coverage of the entire study area.

Approximately 25 percent of the study area (527,564 acres) are least sensitive on the basis of the present ranking criteria. Eighteen percent, (380,677 acres) are moderately sensitive; fifty-six percent (1,183,601 acres) are most sensitive. Water bodies occupy 24,586 acres, or 1 percent of the study area.

Soil map unit delineation boundaries are retained on the sensitivity map. Because of this, in addition to its value as an index to relative map unit sensitivity, the document is a source of regional baseline soil survey information.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions made by the following individuals and agencies, without which this project would not have been possible. Dr. W.J. Walker contributed greatly to development of the computer program which calculated acidification response and provided valuable comments on data analysis. Mr. J-B Chung was responsible for analysis of soil samples at UC Davis and provided excellent data for use in the study. Mr. Daniel Ernstrom of the USDA - Soil Conservation Service assisted in soil correlation and facilitated data transfer from SCS to NORTH STATE RESOURCES. The soil scientists for each of the five national forests included in the study area provided original maps for digitizing, which greatly enhanced the accuracy of the sensitivity map. Special acknowledgement is due the many individual field soil scientists who, over the years, have assembled the soil survey database which is the foundation of the map.

We thank the staff of VESTRA Resources, Inc. for their professional commitment in producing the high quality digitized map. Thanks also to the National Park Service staff, especially Jan van Wagendonk of Yosemite National Park, and David Graber and Dave Parsons of Sequoia National Park for logistical support. We thank Dr. Gordon Huntington of the University of California at Davis for sharing with us soil survey and soil chemical data for Sequoia National Park.

NORTH STATE RESOURCES' soil scientists Dennis Worrel, Russell Almaraz, and Sanderson Page completed field mapping. Laura Kuh assisted in the technical review; Shirley Park typed the report.

The authors extend special thanks to the California Air Resources Board, especially Dr. Kathy Tonnessen, for their patient support of this effort.

DISCLAIMER

"The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products."

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SUMMARY AND CONCLUSIONS

BACKGROUND

An important statutory goal of the Air Resources Board is to determine where acid deposition is occurring or might be expected to occur in amounts which could be adverse to the environment. The Air Resources Board has funded a number of projects through the Integrated Watershed Study (IWS) at Emerald Lake, Sequoia National Park, to determine the impacts of terrestrial and aquatic acidification on high elevation montane ecosystems. Future research will attempt to place the results of the IWS in a regional context. Soil bodies are suitable for grouping ecological systems with respect to their response to acid deposition and, therefore, may be used to extend the IWS findings to wide geographic areas.

This project has two objectives. The first objective is to use taxonomic soil survey information to rank soil bodies in terms of physical and chemical characteristics which may influence watershed response to acid deposition. The second objective is to create a map of soil bodies which shows their geographic distribution and their relative capacities to attenuate acid inputs. The study also provides baseline information to compare soils characteristics in different watersheds.

APPROACH

The study area encompasses the frigid and cooler, cryic soil temperature regimes of the western slope of the Sierra Nevada. The northern boundary is the middle fork of the Yuba River; the southern boundary occurs within the Sequoia National Forest. Response rankings are limited to areas that have been taxonomically surveyed or that were surveyed as part of this project; rankings are provided for approximately 2,116,448 acres.

A computer program, based on published existing models of soil buffering and response to acid inputs, was developed to calculate relative changes in base saturation and pH for the soils in the study area. The computer program was based on soil exchange reactions and aluminum solubility coupled with solution parameters. The exchange equilibria was fitted to a range of soils collected from throughout the study area and then applied to the remaining soils. Individual soils were ranked according to their calculated response to 50 years of acidification at $0.3 \text{ kmol H}^+/\text{ha}/\text{yr}$. Response to added sulfuric and nitric acid was measured directly in a number of soils.

Slope and hydrologic soil group (an index of runoff potential) were considered along with base saturation and pH response to rank aggregations of individual soil types, the soil map units, by their relative capacities to attenuate acid inputs. Map units with relatively small attenuation capacity and relatively high runoff potential are termed "most sensitive." Units with relatively large attenuation capacity and relatively low runoff potential are termed "least sensitive." Map units with intermediate characteristics are termed "moderately sensitive."

Soil map unit boundaries were digitized from published reports. The map was plotted at 1:62,500 scale. Map unit delineations were hatched to indicate the sensitivity class ranking. The map is registered to identical scale USGS 15-minute quadrangles; portions of forty-five 18-inch x 24-inch sheets are required for coverage of the entire study area. The soil survey report for areas within the national parks mapped under this effort, and the database describing soil characteristics in the study area are submitted as Appendices A and B, respectively.

RESULTS AND CONCLUSIONS

This study ranks survey area map units in terms of their relative capacities to attenuate acid inputs. Soil map units with small capacities relative to other survey area map units are termed "most sensitive." Map units with greater capacities are termed "moderately

sensitive" or "most sensitive." Quantification of the ecosystem response to acid deposition is beyond the scope of this study due to the complexity and variability of the process involved throughout the approximate 2-million-acre study area.

Approximately 527,564 acres, or 24.9 percent of the study area, is considered least sensitive relative to the remaining 75.1 percent of the study area. Eighteen percent of the area, approximately 380,677 acres, is moderately sensitive. Almost 56 percent of the study area, or 1,183,601 acres, is most sensitive. Water occupies 24,586 acres, or approximately 1.2 percent of the study area.

Typically the least sensitive soil map units contain non-sensitive soils more than 40 inches deep. Least sensitive soil map units are level or gently sloping landscapes and include little rock outcrop or other miscellaneous land types.

Moderately sensitive soil map units contain shallow, non-sensitive soils on steep slopes and sensitive soils on slopes less than 35 percent. Highly sensitive soil map units contain sensitive soils on slopes steeper than 30 percent. Also, map units that contain 50 percent miscellaneous land type are considered highly sensitive, regardless of other characteristics.

Effective soil depth is an important determinant of soil sensitivity within the study area. Initial base saturation, pH, parent material, cation exchange capacity, and organic carbon content were somewhat less influential. The relative importance of soil characteristics in determining sensitivity varied according to soil horizon.

RECOMMENDATIONS

1. The soil survey (i.e., map sheets and database tables) should be used as a tool for comparing soil characteristics of watersheds throughout the 2-million-acre study area. Understanding watershed similarities and differences will assist the ARB in selecting representative locations for future study and monitoring of a variety of environmental characteristics in addition to soils.
2. Soil survey information should be used to:
 - o Refine the USGS watershed model;
 - o Refine regional lake acidification models; and,
 - o Develop, calibrate and test a mechanistic watershed model.
3. Soil survey information should be used as baseline data to monitor changes in edaphic factors in forested areas of California.
4. The graphics element of this project should be linked to the database element to create a true geographic information system (GIS). The GIS could then be used by other researchers to compare environmental characteristics and to simulate the ecological response to acid deposition over large areas.
5. Additional soil samples, presently archived, should be analyzed. The chemical data should be used to refine the sensitivity model and to improve the integrity of the baseline data.
6. An effort should be made to quantify the importance of forest litter layers and the effects of fire and other management practices on soil response to acid inputs.

7. Soil survey data are widely used in wildland resource management. The Air Resources Board should establish cooperative agreements with land management agencies to share the cost of assembling soil survey information in a consistent format throughout the forested portions of California.

INTRODUCTION

Monitoring by the California Air Resources Board (ARB) demonstrates that acid deposition occurs in various regions of California (California Air Resources Board, 1986; Blanchard, et al., 1989). Both wet and dry deposition occur. Information describing wet deposition is more complete than information describing dry deposition. In general, rates of deposition recorded in California are less than deposition rates recorded in the northeastern United States and in western Europe.

Atmospheric acid deposition is a naturally occurring process. Deposition rates measured in the frigid and cryic soil temperature regimes of the Sierra Nevada represent an addition to natural acidifying processes. Forest ecosystems and montane lakes can be sensitive to changes in soil and water chemistry caused by increased atmospheric inputs of strong mineral acids (Schofield, 1976; Ulrich, et al., 1980).

At present, the growth and vigor of California forests appear unaffected by acid deposition (Peterson, et al., 1989). Although recent research suggests reserves of acid neutralizing capacity are small or absent in some Sierran watersheds (Sickman and Melack, 1989; Brinkley and Richter, 1987), evidence linking the acidification of California montane lakes to atmospheric deposition is weak. Time lags are involved in the response of ecological systems to acidic inputs (U.S. Environmental Protection Agency, 1985), and portions of California may differ in their response to acid deposition because of differences in surface water chemistry, geology, and soil type (National Acid Precipitation Assessment Program (NAPAP), 1982). The extent of ecosystems that respond to increased acid deposition and the significance of the relative responses of individual watersheds are not well understood, yet these are important issues that have obvious implications for public policy decisions.

No definition of sensitivity to acid deposition is generally accepted for all situations. Sensitivity may be defined differently for aquatic systems compared to forest ecosystems.

In this study, soil map unit sensitivity is defined on a relative basis. The relative ranking is based on calculated soil response to acid input, soil properties that influence runoff and retention time, and slope. The scope of this study is limited to development of a relative ranking of map unit response to deposition.

The California Air Resources Board has sponsored research to determine the degree and mechanisms by which acid deposition affects natural ecosystems. The ARB has funded a number of projects through the Integrated Watershed Study (IWS) at Emerald Lake, Sequoia National Park, to determine the impacts of terrestrial and aquatic acidification on biological resources. Future research will attempt to place the results of the IWS in a regional context.

A first step in the extrapolation of the IWS studies to the regional level is the adoption of a basis for comparing geographically separate watersheds with respect to their response to acid deposition. Soil bodies are suitable for grouping ecological systems with respect to their sensitivity response to acid deposition for a number of reasons. As the medium for plant growth, soils influence other elements of the biota. The soil mantle acts as a buffer (van Breeman and Wielemaker, 1974; Reuss and Johnson, 1986; Ulrich, 1980). Soil and surficial geologic deposits influence watershed hydrologic characteristics. Finally, a soil taxonomy has been established to consistently group soils based on the degree to which the environmental factors which control soil formation (e.g., climate, biota, relief, geologic parent material, and time) are expressed as soil physical and chemical properties (U.S. Department of Agriculture, 1975).

PROJECT OBJECTIVES

The first objective of this project is to combine an understanding of the mechanisms of soil acidification with taxonomic soil survey information to rank soil bodies in terms of physical and chemical characteristics which may influence watershed response to acid deposition.

The second objective of this study is to create a map of soil bodies which shows their geographic distribution and relative sensitivity to acid deposition according to the criteria developed.

Sensitivity is defined here as the capacity of a soil body to attenuate acid deposition relative to other soil bodies in the study area. "Soil body" is synonymous with the more technical term "soil map unit." Soil map units are selected as the basis for comparison because they are defined in terms of soil and landscape features which influence the effects of acid deposition on other ecosystem components. Soil response was based on the calculated base saturation that would follow a substantial acid input. Assumed inputs were large in order to emphasize differences in soil buffering capacities. The calculated base saturation was adjusted for soil depth and coarse fragment content. Hydrologic soil group, map unit composition, and map unit slope were considered in assigning a relative sensitivity ranking to each unit.

The sensitivity map produced under this effort serves the objectives of the Kapiloff Act and the Air Resources Board in a number of ways. First, it identifies areas where acid deposition may impact terrestrial and aquatic systems at a relatively detailed level of resolution. Second, it provides a basis for extrapolating the results of related research to larger geographic areas. Third, chemical and physical characteristics measured during this study may be used as baseline data by the ARB as it continues to monitor the effects of acid deposition on terrestrial ecosystems. Finally, the soil and landscape information provided by this study can be used as criteria for selecting locations for future ARB efforts to predict the response of forest and aquatic ecosystems to acid deposition.

STUDY AREA BOUNDARIES

A map of the study area is presented in the Index to Map Sheets included in the map envelope. Sensitivity rankings are limited to areas that have been taxonomically surveyed

or that were surveyed as part of this project; sensitivity rankings are provided for approximately 2,116,448 acres of the approximately 3-million-acre high-elevation west slope Sierra Nevada.

The western boundary is defined in terms of taxonomic soil temperature regimes. The boundary is drawn at the interface between the warmer, mesic regime (downslope, outside) and the cooler, frigid regime (upslope, inside). The cryic regime is included upslope to the crest. The elevation of the mesic-frigid boundary moves downslope with increasing latitude. Accordingly, the western survey boundary occurs at approximately 7,000 feet elevation in the southern Sierra and moves downslope to approximately 5,400 feet in the northern Sierra.

The west slope was selected for study because lakes in Sequoia National Park are thought to be more at risk to acidification than eastern Sierran lakes (Sickman and Melak, 1989), and forest resources are most extensive on the west slope. In addition, previous studies have tended to focus on the west slope. The eastern boundary of the study area is the crest of the Sierra Nevada.

Research indicates that coarse-textured soils derived from intrusive igneous parent materials in cool weathering regimes are among the most sensitive to acid deposition. The northern and southern boundaries of the study area are defined primarily on the basis of geologic characteristics. In order to enhance the usefulness of the existing soil resource database, which is arranged by State soil survey areas, some consideration is given to political demarcations.

The northern boundary is the Middle Fork of the Yuba River, which is north of the main body of the Sierran batholith. The northmost extension of the study area is at approximately 39°31'44" north latitude. The southern limit of the study area is the mesic-frigid interface within the boundary of the Sequoia National Forest, or the forest

boundary. The southernmost extension of the study area is at approximately 35°45'00" north latitude.

The study area includes the surveyed, frigid, and cooler cryic soils which occur in the main body of the western slope of the Sierran granitic batholith. Portions of eight state soil survey areas are included. These are the Tahoe, El Dorado, Stanislaus, Sierra, and Sequoia National Forests areas, and the Yosemite, Kings Canyon, and Sequoia National Parks areas. The acreage included within each survey is listed in Table 1.

TABLE 1
STUDY AREA ACREAGE BY STATE SOIL SURVEY AREA

State Soil Survey	State Soil Survey	
<u>Area No.</u>	<u>Area Name</u>	<u>Acreage Included</u>
719	Tahoe National Forest	257,257
724	El Dorado National Forest	334,303
731	Stanislaus National Forest	512,648
750	Sierra National Forest	439,368
760	Sequoia National Forest	454,552
790	Yosemite National Park	43,249
791	Kings Canyon National Park	23,791
792	Sequoia National Park	<u>51,280</u>
	TOTAL	2,116,448

The Emerald Lake Integrated Watershed Study Area and thirty-seven of the lakes sampled in the US-EPA Western Lake Survey Dataset are in the study area. Twenty-one of the lakes studied by Melack, et al. (1985), and twenty of the lakes sampled by the California Department of Fish and Game (McCleneghan, et al., 1985) are also included.

PROJECT RATIONALE

Acid deposition enters the soil via a number of processes and pathways. Deposition is a mixture of acids and salts, with H^+ being an important cation (Reuss and Johnson, 1986), although ammonium input can also be important in some areas (van Breeman, et al., 1982). McFee (1980) listed four parameters which are important to the estimates of soil sensitivity to acid precipitation. These are:

1. Total buffering capacity or cation exchange capacity, provided primarily by clay and soil organic matter.
2. Base saturation of the exchange complex, which related to soil pH.
3. Management systems imposed on the soil, such as liming or other additions.
4. The presence or absence of carbonates in the soil profile.

Most soils act as buffers that resist acidification, although this effect is much diminished in cool, forested regions where a net leaching regime tends to remove cations from exchange sites on clays, organic matter, and oxides, and replaces them with hydrogen ions. The pool of exchangeable cations is limited by the composition of the soil parent material and by weathering rates, whereas the supply of hydrogen is relatively vast so, over time, natural and anthropogenic acidification can occur.

Important soil buffering reactions in forest ecosystems include cation exchange, mineral weathering, organic matter decomposition and microbial respiration, elemental cycling, aluminum precipitation and dissolution, and sulfate adsorption (Binkley and Richter, 1987; van Breeman and Wielemaker, 1974; Ulrich, 1980). If forest soils buffering is dominated by cation exchange processes, mineral weathering, anion adsorption and aluminum reactions (van Breeman and Wielemaker, 1974), because carbonates are normally absent.

A previous effort to classify Sierran soils with respect to their response to acidic deposition found cation exchange capacity, base saturation, and soil pH to be important variables. Those having a lesser influence were soil organic matter, soil depth, and parent material (Wyels, 1986). Weintraube (1986) examined the response of Sierran watersheds to acid inputs and concluded that Eastern Brook Lakes and Emerald Lake watersheds were extremely sensitive to acidification because of the low weathering rates and thin surfacial cover. McColl (1981) developed a model to assess the sensitivity of Sierran soils. In his model cation exchange and the sum of exchangeable bases were important components in assessing sensitivity. He concluded that poorly developed, shallow granitic soils at higher elevations and soils with low exchangeable bases were the most sensitive of those he investigated. The sum of exchangeable bases was the most predictive soil parameter in the model of soil sensitivity developed by McColl. He applied limits of 5 to 15 meq of exchangeable bases to divide the most, moderate, and least sensitive soil groups.

A computer can be used to calculate changes in soil base saturation and pH resulting from acid input. Evaluation of the response of soil map units to acid inputs requires consideration of soil physical properties and environmental factors in addition to soil chemical properties. Taxonomic soil survey information, supplemented by additional chemical analyses, provides baseline soil characterizations which can be used as bases to calculate soil acidification. Soil survey information and the results of the acidification

calculations can be used to rank soil bodies in terms of their relative response to acid deposition.

CONCEPTUAL BASIS FOR ESTIMATING pH AND BASE SATURATION CHANGES IN SIERRAN SOILS

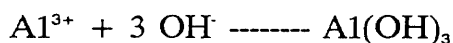
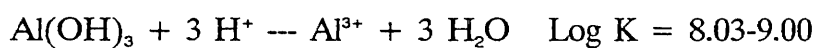
Sierran soils receive wet acidic deposition in two ways. One is through snow pack melt each spring, and the other is through sporadic summer and early fall rain events. Thus, Sierran soils are subject to pulses of acidification (Lund, et al., 1989). This being the case, it can be argued that rapid reactions between added acidity and the exchange complex are important buffering components in Sierran soils since these reactions are rapid enough to react with water as it flows through the soil. Such a reaction sequence can be simulated by an equilibrium reaction since the rate of reaction is faster than the water flow rate in the system. Therefore, an equilibrium model was chosen to simulate the response of Sierran soils to acid inputs.

SOIL CHEMISTRY RELATIONSHIPS INCLUDED IN THE COMPUTER PROGRAM

The following reactions are considered important in determining soil solution composition and in determining how that composition might be altered by acidic inputs suggested in the conceptual framework outlined above. For clarity, the reactions are presented as 'solid phase' and 'solution phase' reactions. Following each reaction is a brief description of its role in soil acidification and the input data necessary to quantify the reaction.

Solid Phase and Cation Exchange Reactions

1. Interlayer aluminum hydroxide or microcrystalline gibbsite solubility.



This reaction may control aluminum solubility in acidic soils. As suggested by the expression, decreasing the pH will dissolve the solid and release aluminum ion to soil solution. Aluminum solution and dissolution may account for a substantial amount of pH buffering in acid soils. Control of solution aluminum by this solubility expression can be tested with ion activity products derived from the soil solution extracts and pH.

2. Exchangeable Aluminum.

$$-\text{Log}(\text{Al}^{3+}) = \text{B}(\text{pH}) + \text{C}$$

Where:

$$\text{B is the slope} = 1.05 \times (\text{bound aluminum ratio}) + 0.345$$

$$\text{C is the intercept} = -(5.47 \times \text{bound aluminum ratio}) + 3.879$$

This empirical relationship was developed by Cronan, et al. (1986) and relates solution aluminum to the amount of aluminum bound to the surface, or the bound aluminum ratio. The bound aluminum ratio is related to base saturation by the relationship: 1 minus bound aluminum ratio = base saturation (sum of Ca+Mg+K+Na ÷ total exchange capacity). Input data necessary to utilize this expression include exchangeable aluminum, sum of exchangeable bases, and pH.

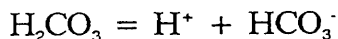
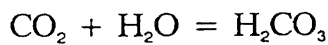
Solution Phase Reactions

1. Aluminum Hydrolysis.



As indicated by the reactions, soluble aluminum can significantly influence solution pH by hydrolysis. Soluble aluminum is determined from pH and either exchangeable or mineral soluble aluminum, and the degree of hydrolysis determined from these equations.

2. Carbonate Equilibria.



These reactions influence the sensitivity of soils to acidic input due to changes in production of alkalinity. In this study the computations are based on estimates of partial pressure of carbon dioxide in the soil atmosphere as well as charge balance considerations useful for estimating alkalinity in natural waters. These data are derived from soil solution composition for cations and anions.

RATIONALE FOR THE ADOPTION OF TAXONOMIC SOIL SURVEY INFORMATION AS THE BASIS FOR ESTIMATING pH AND BASE SATURATION OF SIERRAN SOILS

Taxonomic soil surveys group soil bodies on the basis of physical and chemical properties which are, in turn, controlled by the environmental factors of soil formation. Examples of soil characteristics that are taxonomically significant and which directly or indirectly influence soil sensitivity to acid deposition are organic matter content, particle size distribution and clay content, percent base saturation, coarse fragment content, and depth.

Some chemical parameters which influence sensitivity are not taxonomically significant. Included in this group is exchangeable aluminum. Additional analyses are necessary to supplement the taxonomic database in these situations. However, because it is impractical to perform supplemental analyses on every taxonomic soil component within a 2-million-acre study area, chemical data required as model input often must be extrapolated from sampled components to approximate chemical characteristics of unsampled components.

The extrapolation of data from sampled to unsampled taxonomic components is based on soil correlation. Soil correlation involves consideration of soil physical and chemical properties and observable, taxonomically significant characteristics to group soils with

similar limitations for use and management. An underlying assumption of this study is that principles of soil correlation apply to grouping soils with respect to their response to acid deposition.

PROJECT OVERVIEW

The project includes four phases: soil survey data acquisition and database management; soil chemical characterization; computer program development, calibration, and validation; and data analysis and map production.

Order 3 soil survey is a reconnaissance level of resolution. The minimum area of contrasting soils recognized at the Order 3 level is roughly 50 acres. Order 3 soil survey information at 1:62,500 scale was obtained for the Tahoe, El Dorado, Sierra, and Sequoia National Forests. Order 3 information at 1:24,000 scale was obtained for the Stanislaus National Forest and for the Soil Survey of Sequoia National Park, Central Part (Huntington and Akeson, 1987). Additionally, approximately 106,000 acres within Yosemite, Kings Canyon, and Sequoia National Parks were mapped by NORTH STATE RESOURCES soil scientists at approximately 1:24,000 scale. The soil survey maps and a description of the technical methods are included in Appendix A.

Soil chemical characterization is based on lab analyses of one hundred sixty-seven samples taken from forty-three modal soil profiles throughout the study area. One hundred forty-four of the one hundred sixty-seven samples were analyzed under this research effort. Data for the remaining twenty-three samples are taken from Huntington and Akeson (1987). Locations of sampled soil pedons are given in Table 2. Lab data for analyzed profiles were extrapolated to unanalyzed profiles based on taxonomic similarities and soil correlation procedures. Chemical data are presented in Appendix B, Table B.9. Data sources are presented in Appendix B, Table B.9.

TABLE 2
LOCATION OF SAMPLED SOIL PEDONS

MAP UNIT SYMBOL	SOIL NAME	LOCATION
719CeC	CELIO	SE1/4 SE1/4 Sec 29, T21N, R13E
791FiE	TAHOMA	SE1/4 NW1/4 Sec 32, T19N, R16E
719JwF	JORGE	NE1/4 Sec 8, T15N, R16E
719LcE	LEDFORD	NE1/4 NE1/4 Sec 9, T20N, R13E
719MiE	MEISS	NW1/4 NE1/4 Sec 12, T17N, R13E
719TbE	TALLAC	SW1/4 NE1/4 Sec 21, T17N, R16E
719TiE	TINKER	NW1/4 NW1/4 Sec 24, T17N, R14E
719WaE	WINDY	NW1/4 SW1/4 Sec 6, T18N, R12E
719WoG	WOODSEYE	NW1/4 SE1/4 Sec 30, T17N, R13E
724128	GERLE	NW1/4 SW1/4 Sec 2, T13N, R14E
724132	SMOKEY	NE1/4 SE1/4 Sec 33, T13N, R14E
724158	NOTNED	E1/2 NW1/4 Sec 5, T10N, R17E
724162	LITHIC CRYUMBREPTS	SW1/4 NW1/4 Sec 2, T10N, R16E
724216	WACA	SW1/4 SW1/4 Sec 7, T10N, R17E
731101	ANDIC CRYUMBREPTS	Center Sec 35, T6N, R21E
731106	ENTIC CRYUMBR, M.D.	SW1/4 Sec 27, T6N, R21E
731116	GERLE F.,D	NW1/4 NW1/4 Sec 8, T2N, R19E
731147	INVILLE FAMILY	SE1/4 Sec 28, T4N, R18E
731163	LITHIC CRYOPSAMMENTS	NW1/4 SE1/4 Sec 27, T6N, R21E
731197	WINTONER FAMILY	NE1/4 Sec 9, T4N, R18E
750104	AQUIC DYST XEROCHREP	NW1/4 SE1/4 Sec 27, T5S, R24E
750113	LITHIC XEROPSAMMENTS	NW1/4 NW1/4 Sec 11, T6S, R25E
750115	CAGWIN FAMILY	NE1/4 NE1/4 Sec 12, T8S, R25E
750131	TYPIC XERUMBREPTS	NE1/4 SE1/4 Sec 35, T5S, R2E
750132	ENTIC CRYUMBREPTS	SE1/4 NE1/4 Sec 26, T7S, R26E
750158	SIRRETTA FAMILY	NW1/4 NW1/4 Sec 24, T10S, R27E
750162	STECUM FAMILY	SE1/4 SW1/4 Sec 1, T10S, R27E
750174	UMPA FAMILY	SW1/4 SW1/4 Sec 8, T5S, R24E
760311	MONACHE VARIANT	E1/2 SE1/4 Sec 31, T20S, R32E
760311	SEQUOIA MEADOW	
760409	SIRRETTA	SW1/4 SE1/4 Sec 15, T23S, R33E
760603	CANNELL	NW1/4 Sec 12, T21S, R34E
760609	TOEM	NW1/4 Sec 33, T20S, R34E
760612	JUMPE FAMILY	SW1/4 NE1/4 Sec 24, T23S, R33E
760613	BALD MOUNTAIN	SE1/4 Sec 3, T22S, R34E
760625	NANNY FAMILY	Center Sec 7, T24S, R32E
792AqF	AQUEPTS, FRIGID	NE1/4 SE1/4 Sec 29, T15S, R30E
792CaQ	CRYAQUEPTS	NW1/4 Sec 25, T15S, R30E
792EcF	ENTIC CRYUMBREPTS, L-SK, M	NE1/4 NW1/4 Sec 25, T15S, R30E
792JgoF	LITHIC XERUMBREPTS,S,M,F	NW1/4 SW1/4 Sec 28, T15S, R30E
792LeuD	LITHIC CRYUMBREPTS, L, M	NE1/4 NW1/4 Sec 25, T15S, R30E
792PxbD	PACHIC XERUMBREPTS, C-L,F	W1/4 Line Sec 28, T15S, R30E
792coF	TYPIC CRYORTHENTS	NE1/4 Sec 25, T15S, R30E

The lab data were used as the bases for calculation of the percent base saturation for each soil horizon in the soil profile or to a depth of 60 inches, whichever is shallower. The calculations were calibrated by adding known amounts of hydrogen ion to modal soil samples and recording the pH decrease with time. The depth-adjusted, average base saturation, along with slope and hydrologic soil group, were used as criteria to produce a 13-category relative ranking of soil map unit response to acid deposition. The 13 categories were aggregated into three broad classes and the boundaries of each class plotted on clear mylar registered to 1:62,500 scale USGS topographic maps. The resulting approximately 1 inch = 1 mile scale map of relative soil map unit sensitivity was reproduced using a vellum/blueline process.

STUDY LIMITATIONS

Limitations apply to each phase of the study. The boundaries of sensitive soil bodies are based on Order 3 information, which is a reconnaissance level of resolution. Reconnaissance level information is generally recognized as suitable for regional planning and for making broad comparisons of the characteristics of third order or larger watersheds.

The minimum area of contrasting soils recognized at the Order 3 level - that is, the minimum delineation - is approximately 40 acres. (The minimum delineation for the Tahoe National Forest and Sequoia National Park, Central Part, is smaller than 40 acres). Contrasting soil bodies smaller than the minimum delineation are included in larger bodies. Soil map unit boundaries are plotted by a combination of aerial photo interpretation and on-site verification. Areas without easy access are rarely visited, and as many as one third of the map unit delineations may not have been examined in the field. Often, soil series have not yet been established in upland areas, so the soil taxonomic components of the map units are classified at a higher (more general) level of taxonomy, typically the phase of soil family level. Finally, the map units at the Order 3

level are the more encompassing soil association and soil complex instead of the purer soil consociation.

Hydrologic soil group and map unit slope are criteria for ranking map units in terms of relative sensitivity. These parameters are included to distinguish between map units in terms of their response to short duration, high intensity precipitation events. These are qualitative criteria, and the magnitude of their influence on sensitivity is, to a large degree, indeterminate. Climatological and acid inputs are assumed constant in time and throughout the study area. In fact, microclimate, vegetation patterns, and other environmental characteristics too complex to map at the Order 3 level of resolution influence soil response, but are ignored in this study.

The estimation of soil pH and base saturation is limited by difficulty of extrapolating short term results to longer term processes. Because of its high cation exchange capacity, soil organic matter can be an effective buffer or a source of acidity. Litter and duff are not considered in estimating soil pH and base saturation in this study. This is because the presence and thickness of the litter layer is extremely variable and is not a criterion to differentiate between soils. Also, management activities such as timber harvesting and burning change the amount of litter and the contribution of the forest floor to acid buffering. Even if the thickness of the litter layer could be mapped, the map would be only a representation of the layer at a single, relatively brief point in time. In light of these constraints, the effect of this important source of buffering has been ignored. However, it is important to note that in situations where considerable duff or litter exists, the soil response to acide deposition might be considerably different than that predicted by this calculation.

Input for the calculation of soil response is based on lab characterization of one hundred sixty-seven samples from forty-three taxonomic components. The names and locations of the sampled components are listed in Table 2. Chemical data for unsampled profiles are

based on soil correlation which introduces an element of uncertainty into the calculated response.

Chemical data required to predict soil pH and base saturation are often not included in standard soil survey databases. For example, required data include soil pH, exchangeable bases, exchangeable Al^{3+} , and H^+ . Exchangeable Al^{3+} and H^+ were not available for all sampled horizons, and in these cases were estimated from soil pH and base status by regression analysis.

Other mechanisms which influence pH response and buffering were not incorporated into the calculation because the data were not available or because the process was not amenable to a functional relationship necessary for the program. Although the program can include an empirical correction for mineral weathering, differences among parent materials and changes in weathering rates accompanying pH changes could not be documented and weathering was not included in the pH and base status computations. Decomposition of organic matter may increase pH. However, because decomposition rates vary widely with temperature, moisture, soil microflora, microfauna, litter type, and management activities, the influence of organic matter decomposition was not included in the computations.

These constraints limit the calculation of absolute response of the study soils to acidic inputs. However, determination of an absolute response was not the intent of this study. Rather, the computations were used to determine a relative ranking of soils with respect to their response to acid deposition. The database provides a reference point for these soils. The boundary of the sensitivity rankings can easily and inexpensively be recalculated with different inputs as required.

METHODS

SOIL SURVEY DATA ACQUISITION AND DATABASE MANAGEMENT

Order 3 soil survey information at 1:62,500 scale was obtained for the Tahoe, El Dorado, Sierra, and Stanislaus National Forests. Order 3 information at 1:24,000 scale was obtained for the Stanislaus National Forest and for the soil survey of Sequoia National Park, Central Part. Soil survey information for the National Forests was provided by the respective forests. The Soil Survey of Sequoia National Park, Central Part, was provided by Dr. Gordon Huntington. Additionally, approximately 106,000 acres within Yosemite, Kings Canyon, and Sequoia National Parks were taxonomically mapped by NORTH STATE RESOURCES soil scientists as part of this study.

Study area boundaries are shown in the Index to Map Sheets. Boundaries of the eight survey areas included in the study area can be determined by referring to the map unit sensitivity maps.

NSR applied National Cooperative Soil Survey (NCSS) procedures in mapping the parks. A description of the soil survey methods accompanies the soil survey manuscripts for these acres, included as Appendix A to this report.

To minimize distortion, soil map unit boundaries for most of the Forest Service mapping were digitized from the original mylar overlays used to produce published maps. Overlays for the Stanislaus National Forest and Sequoia National Park were unavailable so map unit boundaries were taken from published maps. NSR map unit boundaries were transferred from 1:24,000 scale mapping photos to identical scale USGS orthophotos. Boundaries were digitized from the orthophotos.

Digitizing was accomplished using Environmental System Research Institute, Inc., (ESRI) pc ARC/INFO, (Version 3.2), software. Digitizing hardware included Wyse 286, Compaq 386, and Compunet 386 computers with a 130 megabyte hard disk drive, and a Cal Comp 9100 36-inch x 48-inch backlit digitizing table. A Cal Comp 1044 8-pin plotter was used for map production.

Map unit descriptions and taxonomic unit descriptions (e.g., polygon attribute data) for the national forests were obtained in magnetic format from the Soil Conservation Service (SCS). These data and the attribute information for the national parks were summarized in a relational database using R-Base System V software.

The structure of the attribute database is similar to that of the State Soil Geographic (STATSGO) database developed by the SCS for planning on regional levels. The database consists of ten tables. Some tables describe map unit or taxonomic unit characteristics; others document the correlation process or show the sensitivity ranking of taxonomic units and map units. Each of the tables is described in the Results and Interpretation section of this report.

The tables are cross-referenced by a shared attribute, the map unit identification symbol, which is common to all tables.

The map unit identification symbol is the numeric or alphanumeric label which appears in each delineation of the sensitivity map. The first three digits of the label (e.g., 719, 724, 731, etc.) identify the state soil survey area (see Table 1 - Study Area Acreage by State Soil Survey Area); the following digits/characters are the map unit symbol within the state soil survey area. It is possible to integrate information from the ten tables to create hybrids by using relational commands.

The attribute data provided by the SCS had, in some cases, been generalized to accomplish objectives unrelated to this project. This situation is especially true for state

soil survey area 719, the Tahoe National Forest. In order to make the model input as representative as possible of soil conditions within the study area, considerable effort was spent replacing STATSGO data entries derived from Soil Interpretations Records (Form-SCS-Soil-5) from outside the survey area with information from pedons described within the study area and provided in the published soil surveys. Put another way, wherever possible, the information contained in the database is taken from modal pedons and the range of characteristics for modal pedons described within the study area. Modal pedons are soil exposures which typify the most commonly occurring expression of a taxonomic component.

SOIL SAMPLING AND SOIL CHEMICAL CHARACTERIZATION

Modal profile locations identified in the soil survey reports were plotted on 15-minute USGS topographic quadrangles. Components were stratified taxonomically and profiles were selected for sampling to provide a representative range of taxonomic characteristics within each survey area and for the study area as a whole. Accessibility also was a sampling criterion. Sampled profiles are identified in the SOURCE table included in Appendix B. Locations of sampled pedons are listed in Table 2.

Sampling was conducted during the summer and fall of 1987. Soil scientists traveled to the precise location of each modal profile and searched for evidence of excavation. Modal profiles were re-excavated; the soil scientist examined the profile and compared the newly exposed surface to the published description to verify the location. The soil profiles were re-described if the horizon thicknesses deviated from the published description by more than a few inches.

Approximately one-kilogram samples were obtained from each horizon and placed in plastic bags. Samples were dried at 60°C and screened to pass a 2mm (No. 10) sieve. The coarse fragments were discarded and all analyses were performed on the less than 2mm fraction.

Chemical characterization of soil proceeded in phases. Rather than determine a suite of soil parameters on all soil samples initially, thirty-six samples representing the range of chemical characteristics anticipated in the full sample set were analyzed to examine relationships among commonly determined soil chemical characteristics and chemical response to added acidity. At the same time, analytical methods were checked for accuracy and consistency. The remaining samples were analyzed when the data for the initial analysis were found to be internally consistent and the analytical results were reproducible within reasonable limits.

The pH of a 1:1 soil:water extract was measured for each of the thirty-six initial samples. Soil response to acidity was determined by adding 6 meq H^+ as nitric and as sulfuric acid to 100 grams dry soil. The 1:1 soil:solution pH was measured after 4 hours. The soils were maintained at constant temperature and the pH was measured a third time after 14 days. Selected samples were also treated with 0.1, 0.5, 1.0, 2.0 and 4.0 meq of H^+ per 100 grams and the pH measured at the same intervals.

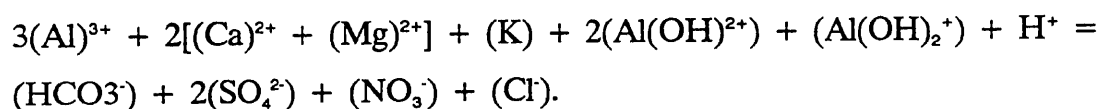
Exchangeable acidity was measured by extraction with 1N KCl and titration with standard base. Extractable Al^{3+} was measured by back titration after addition of NaF (Thomas, 1982). Exchangeable cations were displaced by 1 N ammonium acetate and measured by atomic absorption (Thomas, 1982). The sum of exchangeable cations and exchangeable acidity was used to determine cation exchange capacity (Thomas, 1982).

Organic carbon was determined by the Walkley-Black method (Nelson and Sommers, 1982). Total N was measured by the Kjeldahl method (Bremner and Mulvaney, 1982). Sulfate adsorption was determined by adding sodium sulfate solutions to samples with initial concentrations of 0, 10, 25, 50, and 100 mg/l SO_4 -S and determining the remaining SO_4 -S after equilibration for 48 hours. Sulfate was determined by ion chromatography. Water soluble Ca, Mg, Na, and K as well as sulfate and nitrate were determined on selected samples prior to and following acid additions, by ICP and ion chromatography.

Selected samples were measured to determine the levels of iron and aluminum oxides extracted by oxalate, pyrophosphate, and dithionate (Bascomb, 1968; McKeague and Day, 1966; Mehra and Jackson, 1960). All samples were run in duplicate, and the analyses were repeated on soil pH several times. The average variation between separate runs on the initial 36 samples was 0.088 units with a range of 0 to 0.2 pH units. All analyses were compared against the control limits set in our laboratory.

COMPUTER PROGRAM DEVELOPMENT AND CALIBRATION

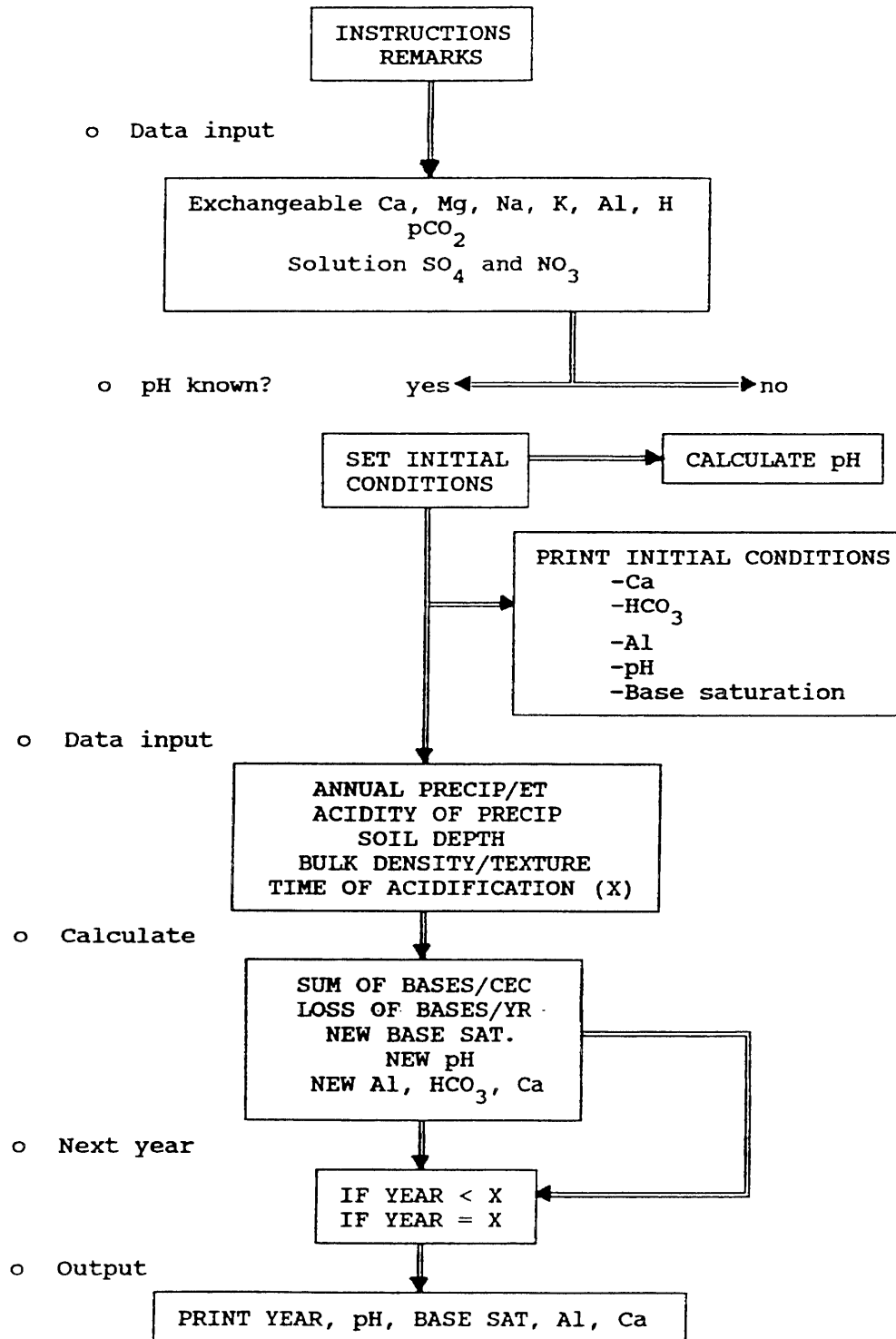
A flow diagram for the calculation of pH and base saturation is presented in Figure 1. First, soil chemistry data are input for exchangeable cations and partial pressure of carbon dioxide. A carbon dioxide partial pressure of 0.005 atmospheres was chosen to represent the increased level of carbon dioxide known in soils. This value has been used in other calculations (Bloom and Grigal, 1985) and is consistent with the level of carbon dioxide found in alpine soils (Solomon and Gerling, 1987). Estimates of soil solution nitrate and sulfate are required when the initial soil pH is unknown. The exchange composition is determined, base saturation calculated, and pH determined if it is an unknown. The pH is calculated in a manner similar to that described by Reuss and Johnson (1985) in which the chemical expressions outlined previously are combined in an electroneutrality expression of the form:



The equation is rearranged in terms of pH and the resulting fifth order polynomial is solved for pH using a Newton-Raphson numerical technique. Once the pH is solved, aluminum speciation and alkalinity are computed. These data are then used to solve the mass balance expressions for cation exchange which will predict changes in soil solution cation concentrations. This part of the calculation uses the available chemistry data to set

FIGURE 1

FLOW DIAGRAM FOR PH AND BASE SATURATION CALCULATION



the initial soil conditions in terms of units compatible with the acidification routines that follow. The output of initial conditions follows. This routine is useful for calculating soil pH under conditions where the pH is unknown or suspect.

Precipitation and evapotranspiration data are input next. Values of 100 cm and 50 cm were chosen for precipitation and evapotranspiration, respectively. Rainfall and snow accumulation are quite variable in the study area and these values were considered to be within the variation encountered in the survey area (Major, 1988). Other values could be substituted, but the relative rankings would change very little. Acid deposition loading was chosen to be 0.3 kmol H⁺/ha/yr, which is higher than current wet deposition rates in California. However, a high value was intentionally selected to distinguish between the responses of different soils. In light of the significant contribution of dry deposition, a loading of 0.3 kmol/ha/yr is not unreasonable. Effective soil depth of the horizon (corrected for coarse fragments), bulk density, and the time of acidification are all possible variables in the calculation. A time of 50 years and bulk density of 1.4 gm/cm³ were chosen.

The computer program is similar to that proposed by Bloom and Grigal (1985) and contains the following assumptions. Sulfate is treated as a mobile anion and therefore not adsorbed by the soil. Although data for sulfate adsorption were obtained for the thirty-six initial samples, no straightforward and reliable prediction of sulfate adsorption can be made with commonly available data. As more sophisticated analyses become available or this process is better understood, the effects of sulfate adsorption can be incorporated into the program.

Second, all horizons are treated as surface horizons. The chosen acid inputs are imposed on each horizon without regard to its location in the profile. The model can be made more dynamic by changing incoming precipitation acidity to lower soil horizons to account for neutralization by the surface horizon.

Third, the properties of the soils are considered to be in a steady state condition. The pH, sum of bases, and base saturation represent an integration of rates of soil weathering, biocycling, additions of organic acids, and leaching of cations from the surface soil. With acidic deposition, the steady state is disturbed and the quantity of exchangeable bases is decreased. Fourth, the effective acidity in wet or dry deposition = $H^+ + NH_4^+ - NO_3^-$. The uptake of a mole of nitrate ions by plant roots results in the release of a mole of basicity. Because of this, nitric acid has no effect in acidification of soils in which plants are growing. Fifth, the volume of water flowing downward from surface horizons is equal to precipitation-evapotranspiration. Sixth, the partial pressure of carbon dioxide in the soil atmosphere is .005 atmosphere (Bloom and Grigal, 1985; Solomon and Gerling, 1987). The last assumption is that soil pH is estimated very well from lab data describing base saturation (BS) by the following expression:

$$pH = pK_a + n \log (BS/(1-BS))$$

Where:

pK_a = the apparent acidity constant for a soil,

n = an empirical constant, and

BS = the base saturation.

This equation describes a sigmoidal variation of pH with BS. This form of other extended Henderson-Hasselbach equation has been successfully applied to the titration of weak acid resins, extracted soil organic matter and peats.

In the computer program, experimentally determined pK_a and n parameters were generated for the soils in the study area using laboratory data for the initial 36 samples. These data gave a value of 5.55 for pK_a over a pH range of 6.4 to 4.8. Therefore, soil pH values outside of this range may not be as well described by the computer program.

The acidification routine proceeds where the loss of bases is calculated on an annual basis by:

$$S = I - A - C$$

where S is the sum of the change in exchangeable bases, I is the effective acidity in wet and dryfall, A is the acid leached from the soil horizon, and C is the decrease in bicarbonate due to the decrease in soil solution pH. The value for A is determined from:

$$A = (3 \times (Al^{3+}) + 2 \times (Al(OH)^{2+}) + (H^+) \times (Precip-ET) \times 100$$

where the pH dependent value for Al^{3+} is computed as described earlier. "Precip" is the annual precipitation and "ET" is the annual evapotranspiration.

The decrease in bicarbonate weathering, C, is given by:

$$C = ((HCO_3)_0 - (HCO_3)) \times (Precip-ET) \times 100$$

where $(HCO_3)_0$ is the initial bicarbonate concentration and HCO_3 is the bicarbonate at the beginning of the computation year.

At the end of each year, a new sum of bases is calculated by subtracting S from the sum of bases for the previous year. A new value for pH is calculated according to the base saturation relationship, new initial conditions are set, and the next year of computation begins. For each year of computation, the program outputs the year, the pH, and the base saturation. Additional output can be requested by exercising the appropriate options. These include soluble aluminum, calcium, bicarbonate and soil solution alkalinity.

In addition to the above routines, the program will consider mineral weathering. Mineral weathering is represented by the following kinetic expression:

$$r = k(H^+)^x$$

where r is the rate of dissolution, k is the apparent rate constant, and x is a constant for a given mineral which generally ranges from 0.5 to 1.0. However, as previously mentioned, there is no provision in the current calculation for changes in weathering rates as pH decreases. Information on the appropriate values for x in these soils is also not available. Therefore, weathering has not been included in the calculations. This omission will affect the relative ranking only if weathering varies significantly among the soil bodies.

The program was calibrated with the soil chemistry data from the thirty-six sample subset which was collected to represent the range of soil properties throughout the study area. The most important calibration was with respect to the pH-based saturation relationship previously described. The range of pH in the initial sample (4.8 to 6.4) sets the range of initial soil pH for which the program has been developed.

RESULTS AND INTERPRETATION

SOIL MAP UNIT DATABASE

The soil map unit attribute database is included in Appendix B and consists of ten tables. Map unit and taxonomic unit characteristics are arranged in columns; map unit identification labels are arranged in rows. The hierarchical structure of the database and a description of the function and information contained in each table follow:

<u>Table/Column</u>	<u>Function</u>
<u>MAPUNIT:</u>	lists map unit name in ascending alphabetical or numeric order by map unit identification label.
includes columns:	<ul style="list-style-type: none"> muid - map unit identification label; the first three digits indicate the State soil survey area and do not appear on the sensitivity map; the remaining digits/characters identify map units within each survey area and do appear on the sensitivity map; muname - map unit name
<u>MURANK:</u>	lists map units by soil survey area in ascending order of sensitivity; provides map unit names and acreages.
includes columns:	<ul style="list-style-type: none"> muid; muname; murank - map unit sensitivity rank; muacres - map unit acreage

COMPED: describes map unit composition by map unit identification label and taxonomic component name.

includes columns: muid;

compname	-	taxonomic component name;
slopel	-	lower percent slope limit for component;
slopeh	-	upper percent slope limit for component;
hydryp	-	SCS hydrologic soil group

COMPTAX: lists taxonomic classification by taxonomic component name (e.g., compname).

includes columns: compname;

class	-	soil taxonomic class
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LAYER: describes soil profile horizons for each taxonomic component by map unit label; these data are the basis for the effective depth calculations used as model input.

includes columns: muid;

compname;

layernum	-	orders horizons, beginning with the surface;
laydepl	-	depth to upper horizon boundary, inches;
laydeph	-	depth to lower horizon boundary, inches;
texture	-	range of USDA soil textures known to occur;
inch3l	-	lower limit of weight percentage of whole soil retained on a 3-inch sieve;

- inch3h - upper limit of weight percentage of whole soil retained on a 3-inch sieve;
- no10l - lower limit of weight percentage of whole soil passing a standard No. 10 sieve;
- no10h - upper limit of weight percentage of whole soil passing a standard No. 10 sieve

SOURCE: assigns a source number to each sample analyzed in this project and to laboratory data developed by Huntington and Akeson for the Sequoia NP, Central Part survey; source number are used in the LABDATA table to identify the source of lab data for unsampled horizons.

includes columns: muid;

compname;

layernum;

laydepl;

laydeph;

source - alphanumeric or numeric code which indicates the soil survey area, map unit symbol, and layer number for each analyzed horizon

PRNTHOR: identifies the horizon nomenclature and parent material for each mineral horizon.

includes columns: muid;

compname;

layernum;

laydepl;

laydeph;

- horizon - major horizonation taken from modal soil profile descriptions;
- prntmat - soil parent material (V = extrusive igneous; GRN = intrusive igneous; MTS = metamorphosed sedimentary; MTV = metamorphosed igneous; MIX = mixed parent materials)

SENRANK: lists taxonomic components in ascending order of the adjusted average percent base saturation simulated by the Sierran soil acidification model after 50 years.

includes columns: compname;

- adav%bs - simulated adjusted average percent base saturation, 50 years

LABDATA: provides actual or correlated laboratory data for each mineral horizon; these data are used as model input.

includes columns: muid;

compname;

layernum;

laydepl;

laydeph;

- source - refer to the SOURCE table for the origin of lab data for unanalyzed horizons;
- pHi - initial 1:1 soil: solution pH;
- HH⁺ - Exchangeable hydrogen ion, meq/100gm soil;
- Al⁺⁺⁺ - exchangeable aluminum, meq/100gm soil;
- Ca⁺⁺ - exchangeable calcium, meq/100gm soil;
- Mg⁺⁺ - exchangeable magnesium, meq/100gm soil;

K ⁺	- exchangeable potassium, meq/100gm soil;
Na ⁺	- exchangeable sodium, meq/100gm soil;
% oc	- percent organic carbon;
cec	- cation exchange capacity, meq/100gm soil

DELTAPH: describes the change in 1:1 soil:solution pH with time following the addition of 6 meq H⁺ as nitric and as sulfuric acid.

includes columns: compname;

layernum;

laydepl;

laydeph;

pHi;

pH1s - soil solution pH four hours after addition of 6 meq H⁺ as sulfuric acid;

pH2s - soil solution pH 14 days after addition of 6 meq H⁺ as sulfuric acid;

pH1n - soil solution pH four hours after addition of 6 meq H⁺ as nitric acid;

pH2n - soil solution pH 14 days after addition of 6 meq H⁺ as nitric acid

SOIL CHEMICAL CHARACTERIZATION

Results of the particle-size analyses and the chemical characterization of the 482 horizons recognized in the study area are presented in the LABDATA and DELTAPH tables, included in Appendix B. Values for initial pH ranged from 4.4 to 6.85. Base saturation (sum of exchangeable cations/sum of exchangeable cations plus exchangeable H⁺ and Al³⁺) ranged from .11 to .99. Organic carbon ranged from 0.11 percent to 12.5 percent;

exchangeable Ca^{2+} ranged from less than the detection limit to 23.8 meq/100gm soil. Concentrations of Mg^{2+} , K^{+} and Na^{+} were undetectable in some horizons. The total exchange capacity (sum of bases and H^{+} and Al^{3+}) varied from 1.5 to 60.3 meq/100gm of soil. Sulfate adsorption at the 100 mg/l initial level varied from 0 to 450 mg/kg of soil in the subset of thirty-six samples analyzed initially.

Buffering capacity would be expected to vary considerably among the soils and horizons because of the variability in these chemical parameters. Clay plus silt content is another important variable which influences soil buffering. However, clay plus silt content varied little among horizons in the study area, partly because of the homogeneity of the soil parent materials.

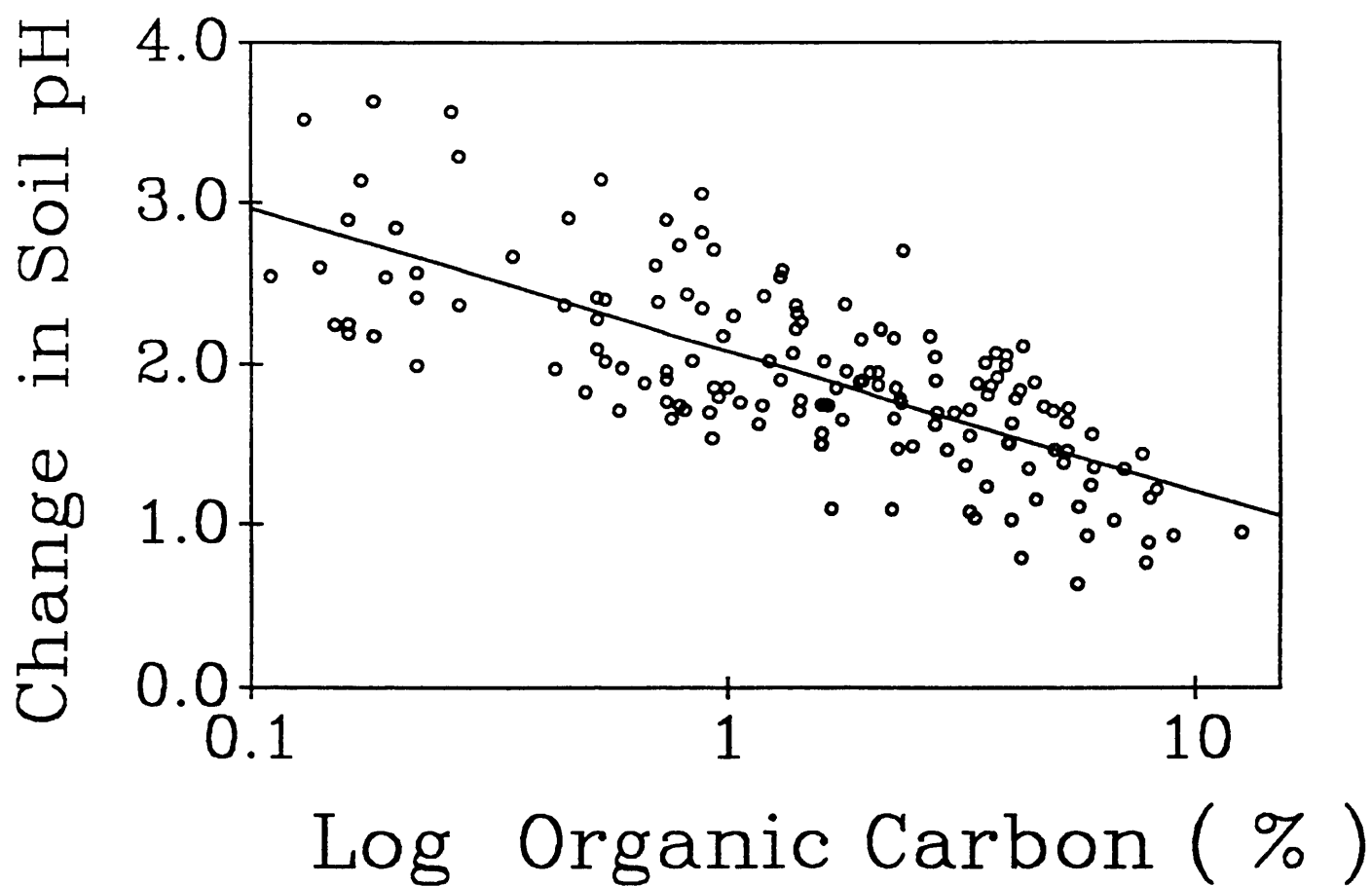
The addition of 6 meq H^{+} /100g soil as nitric acid resulted in substantial pH decreases. The lowest pH induced by this acid addition was 2.9 while the highest pH after acidification was 5.6. As shown in Figure 2, the change, in pH (e.g., initial pH - final pH) resulting from the addition of H^{+} , (ie. the delta pH) was related to organic carbon content. Addition of 6 meq H^{+} /100g soil as sulfuric acid induced a pH change about 0.5 pH unit less than that obtained from nitric acid addition.

The change in pH after acid addition on the final pH after 2 weeks could be used as a direct measure of acid sensitivity. However, this direct experimental approach is not suited to the large number of soils sampled and to those not accessible to direct manipulation. Nonetheless, experimental pH changes were used as an index of sensitivity and the influence of soil properties on sensitivity was examined by regression analysis.

Delta pH after 2 weeks was well correlated with organic matter and the sum of exchangeable bases for the A horizon samples. This relationship was weaker for the B and C horizons.

FIGURE 2

The change in pH following acid addition
in relation to soil organic carbon content



For the A horizon:

$$\text{pH}_{2\text{N}} = 3.35 - 0.089 [(T_o - 4.5) \times \text{OC}] + 0.047 \text{ sum bases}$$

$r^2 = 0.72$, $n = 66$ where $\text{pH}_{2\text{N}}$ is the pH for nitric acid additions after 2 weeks, and OC is organic carbon.

For the B horizon:

$$\text{pH}_{2\text{N}} = 3.28 - 0.194 [(T_o - 4.5) \times \text{OC}] + 0.025 \text{ sum bases}$$

$$r^2 = 0.60, n = 40$$

For the C horizon:

$$\text{pH}_{2\text{N}} = 3.30 - 0.126 [(T_o - 4.5) \times \text{OC}] + 0.018 \text{ sum bases}$$

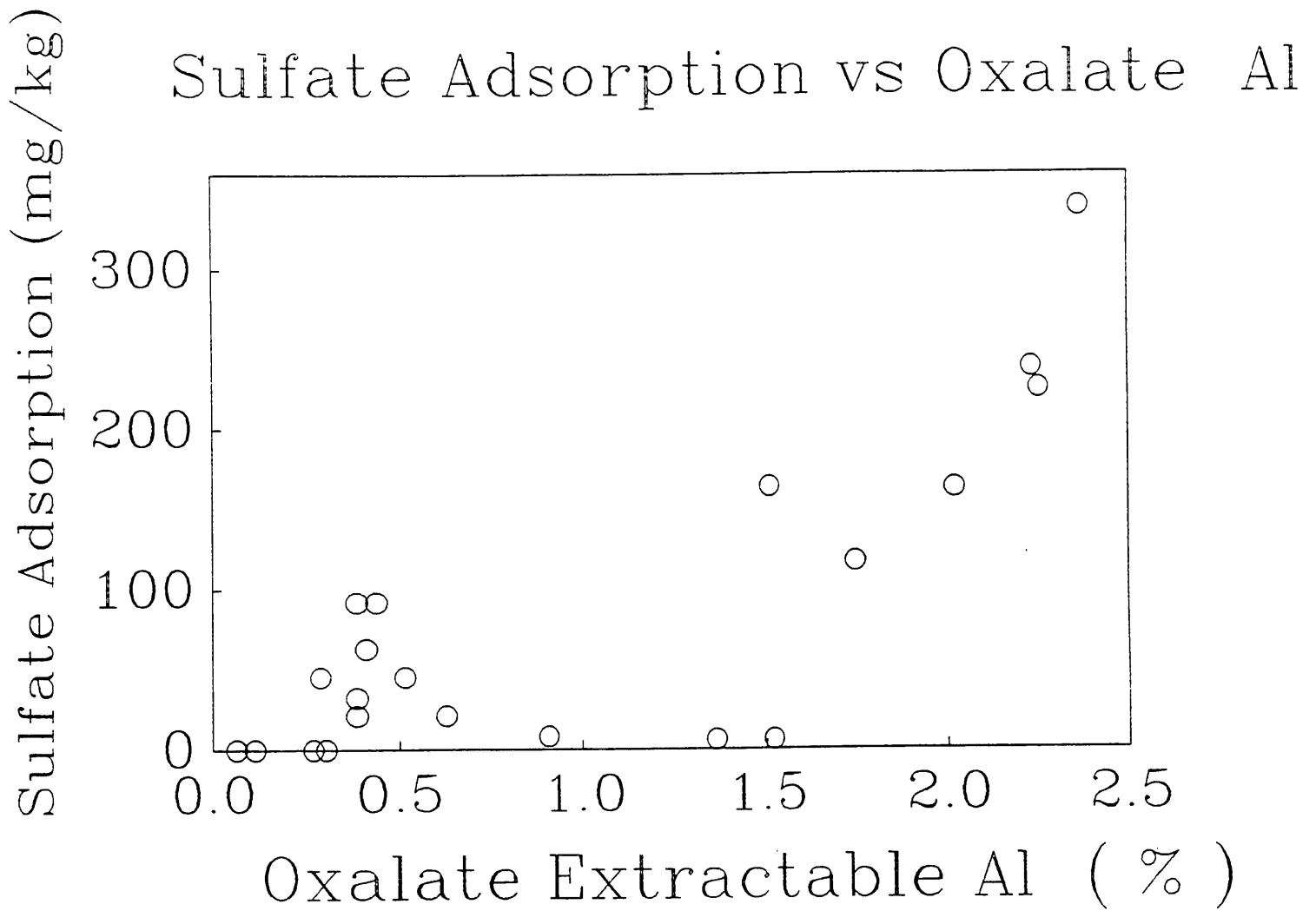
$$r^2 = 0.34, n = 47$$

In the A horizon, organic matter or an undetermined property related to organic matter was strongly controlling soil response to acid addition. Delta pH was strongly related to the initial pH in the C horizons ($r^2 = 0.809$, $n = 47$), and less well related in the B and A horizons, ($r^2 = 0.615$ and 0.28 , respectively).

Sulfate adsorption and extractable iron and aluminum were determined for some of the thirty-six sample subset initially analyzed. Sulfate adsorption varied from 0 to 450 mg/kg among the samples, but was not related to commonly determined soil characteristics such as pH, base saturation or particle-size distribution. As shown in Figure 3, sulfate adsorption was reasonably well related to oxalate-extractable Al.

Based on laboratory analyses and regression analyses, soil pH changes were related to organic matter content, initial pH, and the sum of exchangeable bases. These parameters are considered implicitly or explicitly in the acidification program.

FIGURE 3



RELATIVE RANKING OF SOIL TAXONOMIC UNITS AND SOIL MAP UNITS BY SENSITIVITY RESPONSE

Data from the LABDATA and LAYER tables were used as input for the calculation of percent base saturation and adjusted-average percent base saturation. An input of 0.3 kmol H⁺/ha/yr was chosen for a 50-year period as discussed previously. Adjusted-average percent base saturation is defined as the weighted-average percent base saturation for horizons from modal soil profiles, base saturation values for horizons being weighted on the basis of horizon thickness. The average value is adjusted based on the data contained in the LAYER table to compensate for coarse fragments which are assumed inert. The resulting values for adjusted-average percent base saturation are presented in ascending order in the SENRANK table in Appendix B.

Previous studies have demonstrated that at about 15 percent base saturation, solution Al³⁺ increases dramatically with further reductions in exchangeable non-acidic cations (Reuss 1983). At 15 percent base saturation, pH is also in a region where soluble Al³⁺ generally increases rapidly with further acidification. Therefore, a base saturation of 15 percent after 50 years of acidification was chosen as the separation between sensitive soils and non-sensitive soils. Eighty-eight of the 162 taxonomic units included in the study area - about 54 percent - are sensitive by this criterion.

A fourteen-cell matrix was constructed to rank soil map unit sensitivity. Sensitivity criteria included simulated adjusted, average-percent base saturation (from the SENRANK table), hydrologic soil group, and percent slope.

Previous studies have cited the influence of soil permeability on watershed response to acid deposition (Lund, et al., 1987). Hydrologic soil group and slope are included as sensitivity criteria because these are commonly reported taxonomic unit and map unit attributes (respectively) which permit comparison of map units in terms of the length of time during which precipitation may react with soil and the degree to which reactions involving the solid and liquid phase approach equilibrium.

A hydrologic soil group is a group of soils having the same runoff potential under similar storm and cover conditions. Four main groups are defined: A, B, C, and D. Soils in group A have high infiltration rates when thoroughly wetted, and, by inference, rapid subsoil permeability. Soils in group D have low infiltration rates, and are, by inference, slowly permeable or shallow.

The hydrologic soil group for the dominant taxonomic unit was applied to the entire map unit. Map units composed of more than 50 percent miscellaneous land types were placed in cell 13; water bodies were placed in cell 14. The matrix table is presented in Table 3.

Broad soil map unit sensitivity classes were defined by aggregating the contents of the 14-cell matrix as follows:

<u>Cell Numbers</u>	<u>Sensitivity Class</u>	<u>Acres</u>	<u>Percent of Study Area</u>
1, 2, 3, 4, 5	Least Sensitive	527,564	24.9
6, 7, 8	Moderately Sensitive	380,677	18.0
9, 10, 11, 12, 13	Most Sensitive	1,183,601	55.9
14	Water	<u>24,586</u>	<u>1.2</u>
		2,116,428	100.0

TABLE 3

MAP UNIT SENSITIVITY CRITERIA
(Number of Map Units per Cell)

Map Unit Slope	<35%		30 - 50%		>50%	
Hydrologic Soil Group	A + B	B + C	A + B	B + C	A + B	B + C
Sensitive Soils Comprise Less Than 50 Percent of Unit	Cell#1 (42)	Cell #2 (6)	Cell#3 (39)	Cell#4 (3)	Cell#5 (18)	Cell#6 (3)
Sensitive Soils Comprise at Least 50 Percent of Unit	Cell#7 (29)	Cell#8 (34)	Cell#9 (20)	Cell#10 (18)	Cell#11 (24)	Cell#12 (39)
Miscellaneous Land Types Comprise at Least 50 Percent of Unit	Cell#13 (86)					
Water	Cell#14 (8)					

MAP OF SOIL MAP UNIT SENSITIVITY TO ACID DEPOSITION

The digitized soil map unit delineations were shaded according to the broad sensitivity classes. The map was plotted at 1:62,500 scale on clear mylar. The 18-inch by 24-inch mylar overlays were registered to identical scale USGS 15-minute quadrangles, and vellum reproductions were made from the composites. Blueline reproductions were then made from the vellums which show individual soil map unit boundaries identified by the map unit symbol within each soil survey area. Individual soil survey area boundaries are also shown. The graphic data are superimposed on USGS topographic and cultural data.

Portions of forty-five individual 15-minute quadrangles are required for coverage of the 2,116,428-acre study area. A 1:85,700 scale (1 inch ~ 16 miles) index to map sheets is included in the map envelope attached to this report. Also included in the map envelope is one of the forty-five individual map sheets which serves as a sample of the complete map.

DISCUSSION

The sensitivity of soil taxonomic units to acid deposition can be assessed in different ways. There are long-term reactions and short-term reactions which attenuate acid inputs. Most approaches have emphasized the short-term responses because the longer-term responses are more difficult to quantify and predict. These difficulties arise because experimental data are lacking, and the mechanisms of long-term response are extremely complicated. Wyles (1986) summarized the approaches taken by several researchers and developed a sensitivity classification for Sierran soils based on several soil properties including initial pH, cation exchange capacity, base saturation, organic carbon, soil depth, and parent material. LeVine and Ciolkosk (1988) found base saturation, sum of exchangeable bases, and soil pH to be related to soil sensitivity in Pennsylvania.

The results of this study indicate that base saturation, pH, parent material, cation exchange capacity, soil depth, and organic carbon all influence soil response to acid deposition. Organic carbon was more important in the surface horizons and initial pH was more important in the lower horizons. A combination of initial pH, sum of the base cations, and organic carbon was strongly related to the decrease in pH after acid addition in the organic-rich A horizon samples, but the relationship was less predictive in the lower horizons.

The Sierran soil acidification model was developed to predict pH and base saturation given acid additions. The model uses pH, base saturation, exchange capacity and developed exchange relationships to perform the simulation. Effective soil depth (soil depth minus depth occupied by coarse fragments) is also an important input to the model.

Any classification system which ranks a continuous variable must arbitrarily divide the data set into categories. One option would be to present the rank of each soil relative to all

others and avoid the complications of selecting classes. This approach is not well suited to cartographic representation. We therefore chose to divide the soils into three sensitivity classes based on average-percent base saturation. Average-percent base saturation was chosen as an index of taxonomic unit sensitivity because it is related to pH and aluminum saturation.

Reuss (1983) and Reuss and Johnson (1986) have demonstrated that an abrupt transition in soluble Al occurs around 5 to 15 percent Ca^{2+} saturation. Depending on assumptions and solution parameters, soluble Al^{3+} increases rapidly as exchangeable Ca^{2+} decreases below this range. Soluble Al^{3+} and the attendant low Ca, Mg, and K saturation and other nutritional changes have been implicated in a number of processes and factors affecting forest growth and vigor (cf. Binkley, et al., 1989). Fifteen percent base saturation was selected to distinguish between sensitive and less sensitive soils on this basis.

Base saturation was calculated using a computer program as described earlier. The program used acid inputs of 0.3 kmol H^+ /ha/yr for a 50-year period. Depositional rates vary within the study area, and the chosen value is higher than contemporary wet deposition inputs. A high input value was intentionally chosen to stress the soil system and distinguish between the responses of individual soil types. Dry deposition is substantial; Air Resources Board measurements suggest dry deposition may be many times the wet deposition (ARB, 1986). A value of 0.3 kmol/ha/yr is reasonable given the study objectives, the potential contribution of dry deposition, and values measured elsewhere. Finally, simulations generated by our computer program also generally agree with the direct measurement of response to acid additions in the laboratory. Simulations with lower acid inputs for shorter time periods resulted in nearly identical ranking among the soils.

To summarize, 88 of the 162 taxonomic units recognized in the study area are considered sensitive based on the simulated 50-year percent base saturation criterion. Map unit slope and hydrologic soil group are combined with the taxonomic unit criterion to define map

unit sensitivity. Three hundred sixty-nine (369) map units have been defined. Using the present system of classification, 188 map units (roughly 29 percent) are considered least sensitive; 66 map units (roughly 18 percent) are considered moderately sensitive; 187 map units (roughly 51 percent) are most sensitive.

Acreages and percent of the study area occupied by each sensitivity class are given in the preceding section. Approximately 56 percent of the survey area - 1,183,601 acres - is included in the most sensitive class. Over 650,000 acres of the most sensitive class are map units of which at least 50 percent is a miscellaneous land type (e.g., rock outcrop, talus, glacier, etc.). It is reasonable to assume that the acreage assigned to the most sensitive class would decrease if more detailed mapping which permitted a differentiation between soil and nonsoil were completed.

Nonetheless, the study demonstrates that Sierran soils of the frigid and cryic soil temperature regimes are generally sensitive to strong mineral acid addition. With few exceptions they are coarse textured and low in exchange capacity. Often they are lithic or moderately deep and have coarse fragment contents that exceed 35 percent of the whole soil by weight. These properties dispose the soils to a low buffering capacity, and this was demonstrated in the laboratory.

There were relatively small differences in texture among the soils, and this limited the usefulness of the exchange capacity as a predictor of buffering. If the frigid and cryic soils were compared to the more variable soils of the mesic and thermic soil temperature regimes, it is likely that texture and cation exchange capacity along with other soil properties would be distinguishing characteristics.

In the present study area, the sum of exchangeable bases, organic matter content, and effective soil depth were the most important variables affecting soil response to acid deposition. Parent material was also generally indicative of buffering capacity. Soils

weathered from extrusive igneous parent materials were less sensitive than their intrusive igneous counterparts.

The present sensitivity ranking system appears to work well on cryic and frigid Sierran soils for which commonly measured chemical and physical properties are known. The ranking system should work on more variable soils, but additional calibration of the calculation would be required. Modification and refinement of the map unit criteria is also required before the classification system can be applied outside the present study area.

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LIST OF PUBLICATIONS RELATED TO THIS RESEARCH

TITLE: pH Buffering of Frigid and Cryic Sierra Nevada Soils

AUTHORS: R.J. Zasoski, W.J. Walker, and J.B. Chung,
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PRESENTATION: Poster Session, American Society of Agronomy
Annual Meeting, November 27 to December 2, 1988

ABSTRACT:

Ten modal profiles representing a range of soils from the central California Sierra Nevada mountains were evaluated for pH buffering against strong mineral acids. Thirty-six horizons from the cryic and frigid soil zones were selected to represent a range of parent material and soils characteristics in this region. In these soils organic carbon ranged from 1.3 to 92 g kg⁻¹, and initial pH varied from 4.7 to 6.4. Exchangeable acidity ranged from 0.1 to 2.3 cmol kg⁻¹. Decreased pH associated with nitric and sulfuric acid additions was related to parent material, initial pH and sulfate adsorption characteristics. These parameters in addition to exchangeable and soluble cations and sulfate adsorption were used to develop and calibrate a short-term pH buffering model. The equilibrium model was tested on 30 additional profiles (96 horizons) and found to describe the buffering quite well. The model and output will be presented.

GLOSSARY OF TERMS

adjusted average percent base saturation - The base saturation, expressed in decimal terms, for the whole profile or to 60 inches depth, whichever is shallower, calculated from the average of the base saturation values for individual soil horizon, weighted on the basis of horizon thickness and coarse fragment content.

adsorption - The process by which atoms, molecules, or ions are taken up and retained on the surfaces of solids by chemical or physical binding, e.g. the adsorption of cations by negatively charged minerals.

percent base saturation - The extent to which the adsorption complex of a soil is saturated with alkali or alkaline earth cations expressed as a percentage of the cation-exchange capacity, which may include acidic cations such as H^+ and aluminum.

buffering capacity - The ability to neutralize both acids and bases in solution.

bulk density - The mass of dry soil per unit bulk volume.

cation-exchange capacity - The sum of exchangeable cations that a soil, soil constituent, or other material can adsorb at a specific pH. It is usually expressed in milliequivalents per 100 grams of exchange.

cryic soil temperature regime - A soil temperature regime that has mean annual soil temperatures of more than 0C but less than 8C, more than 5C difference between mean summer and mean winter soil temperatures at 50cm, and cold summer temperatures.

pH - The negative of the logarithm of hydrogen ion concentration in aqueous solution: low pH is acid, high pH is alkaline, pH of 7 is neutral.

differentiae - The distinguishing attribute of any entity.

digitized - Computer process whereby cartographic information is stored, manipulated, and retrieved by assigning spatial coordinates to graphics elements and linking these coordinates to a descriptive database.

duff - Decaying vegetable matter covering forest ground.

effective depth of soil horizon - The depth of mineral soil, adjusted to compensate for the volume occupied by coarse fragments larger than 2mm.

exchange capacity - The total ionic charge of the adsorption complex active in the adsorption of ions. See cation-exchange capacity.

GLOSSARY OF TERMS, Cont'd

exchange acidity - The titratable hydrogen and aluminum that can be replaced from the adsorption complex by a neutral salt solution.

exchangeable ions - Exchangeable ions adsorbed by a soil, clay, or organic matter.

frigid soil temperature regime - A soil temperature regime that has mean annual soil temperatures of more than 0C but less than 8C, more than 5C difference between mean summer and mean winter soil temperatures at 50cm, and warm summer temperatures.

hydrolysis - Chemical decomposition in which a compound is divided into other compounds by taking up the elements of water.

hydrologic soil group - A group of soils having the same runoff potential under similar storm and cover conditions.

infiltration rate - The rate at which water enters the soil.

ion chromatography - Separation of ions by a method in which the ions in solution are separately adsorbed in colored layers of an adsorbent to facilitate the analysis of mixtures.

mapping unit - A cartographic aggregation of soil taxonomic units associated with non-soil land features including slope, parent material, vegetation, etc. Soil surveys are composed of individual mapping units.

mesic soil temperature regime - A soil temperature regime that has mean annual soil temperatures of 8C or more but less than 15C, and more than 5C difference between mean summer and mean winter soil temperatures at 50cm.

minimum delineation - The minimum area for which differing soil or landscape conditions are recognized. The minimum delineation is largely determined by the scale of the mapping photography.

miscellaneous land type - A mapping unit for areas of land that have little or no natural soil, that are too nearly inaccessible for orderly examination, or that for any reason it is not feasible to classify the soil.

modal pedons - The actual soil body which typifies the central concept of a taxonomic unit (i.e., the most common condition of the soil) in terms of diagnostic criteria including presence and arrangement of horizons, coarse fragment content, soil parent material, etc.

GLOSSARY OF TERMS, Cont'd

The modal pedon is identified after studying many individuals to determine the range of characteristics.

orthophotos - Stereoscopic photographs that have been altered to minimize scale distortion.

parent material - The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of soils is developed by pedogenic processes.

relational database - A collection of data items which are referenced to one another by a shared attribute; relational databases are well-suited to determining relationships among data elements.

runoff - That portion of the precipitation on an area which is discharged from the area through stream channels and sheet flow.

soil association - (i) A group of defined and named taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region. (ii) A mapping unit used in which two or more defined taxonomic units occurring together in a characteristic pattern are combined because the scale of the map or the purpose for which it is being made does not require delineation of the individual soils.

soil complex - A mapping unit used where two or more defined taxonomic units are so intimately intermixed geographically that it is undesirable or impractical, because of the scale being used, to separate them. A more intimate mixing of smaller areas of individual taxonomic units than that described under **soil association**.

soil consociation - A mapping unit used in which a single taxonomic unit is clearly the most common, typically occupying up to 80 percent or more of each delineation.

soil correlation - The process of determining the range of soil characteristics appropriate to a taxonomic unit; implicit in the process is the extension of data by inference and thus achieve a conjectural knowledge of the unknown.

soil family - The lowest (most restrictive) taxon of the USDA Soil Taxonomy; family criteria include texture, mineralogy, reaction, soil temperature, and thickness of horizons.

soil horizon - A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as color, structure, texture, consistency, kinds and numbers of organisms present, degree of acidity or alkalinity, etc.

GLOSSARY OF TERMS, Cont'd

soil solution - The aqueous liquid phase of the soil and its solutes.

soil taxonomy - A system of classification which aggregates soils in categories to facilitate study and comparison.

Solum - The upper and most weathered part of the soil profile; the A and B horizons.

taxonomic unit - A categorical aggregation of soils with similar characteristics; a "soil type"; soil mapping units are composed of taxonomic units.

thermic soil temperature regime - A soil temperature regime that has mean annual soil temperatures of 15C or more but less than 22C, and more than 5C difference between mean summer and mean winter soil temperatures at 50 cm.

**SURVEY OF SOIL MAP UNIT SENSITIVITY TO
ACID DEPOSITION IN THE SIERRA NEVADA, CALIFORNIA**

**Appendix A- Soil Surveys of Portions of Yosemite, Kings Canyon,
and Sequoia National Parks**

Appendix B - Taxonomic Unit and Map Unit Attribute Database

Contract No. A733-037

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FEBRUARY 1990

APPENDIX A

SOIL SURVEYS
OF PORTIONS OF

YOSEMITE NATIONAL PARK
KINGS CANYON NATIONAL PARK
SEQUOIA NATIONAL PARK

Supplemental Text To

SURVEY OF SOIL MAP UNIT SENSITIVITY
TO ACID DEPOSITION
IN THE
SIERRA NEVADA, CALIFORNIA

APPENDIX A: SOIL SURVEYS
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SOIL SURVEYS CONDUCTED WITHIN
YOSEMITE, KINGS CANYON, AND SEQUOIA
NATIONAL PARKS

INTRODUCTION

Soil survey information is available for the majority of the cryic and frigid western slope of the Sierra Nevada, with the notable exception of the National Parks. Approximately 680,500 unsurveyed acres occur within Yosemite; approximately 223,000 acres occur within Sequoia; and approximately 454,700 acres occur within Kings Canyon.

An important element of this project was to complete as much soil survey in these areas as financially possible and to use these resulting baseline data to rank soil map units in terms of their sensitivity response to acid deposition.

Potential survey areas were selected based upon a review of unsurveyed high alpine areas within the Study Area, proximity to alpine lakes sampled by other researchers, and anticipated sensitivity. Two or three alternatives were selected within each National Park. The final determination was based on:

- o Availability of aerial photographs
- o Availability of physical access into each area
- o Permission by the National Park Service
- o Approval by the Air Resources Board

Approximately 106,000 acres were selected for Order 3 soil survey, distributed among the parks in the following manner:

- o Tuolumne Meadows area, Yosemite National Park
(43,000 acres)

- o Dougherty Peak area, Kings Canyon National Park (25,000 acres)
- o Kern Canyon area, Sequoia National Park (38,000 acres)

METHODS

The surveys were conducted by professional soil scientists who applied the standards of the National Cooperative Soil Survey. Soils were classified according to the USDA Soil Taxonomy.

Available information describing the physical and biological characteristics of each survey area was collected and reviewed in detail. Nearby soil surveys were also reviewed as available. Map unit legends for adjacent areas served as a guide for developing the preliminary map unit legend for each area. Soil families were used as the basic taxonomic component.

Topographic maps and aerial photography for the study area were obtained prior to field activities. Mapping photos for the Sequoia and Kings Canyon areas were 1:22,000 scale black-and-white photos obtained from the National Park Service National Cartographic Center. Mapping photos for the Yosemite area were 1:15,000 scale color infrared photos obtained from the Yosemite Park Naturalist. The survey area boundaries were transferred to frosted acetate photo overlays.

For the Order 3 surveys, the minimum size delineation was 50 acres.

Map units were identified by transecting representative land units. Soil scientists examined and identified the soil at selected intervals to record soil characteristics and document other field observations. The observations were recorded on a standard form to maintain consistency in the data collection.

The results of a number of transects were summarized to verify the relative proportions of dominant and included soils e.g., taxonomic units) occurring within each mapping unit. Mapping unit boundaries were then plotted by observation and interpretation of aerial photographs. Observations were field-verified whenever necessary to maintain accuracy.

The specific information collected during the field survey includes the following:

- o Detailed descriptions of the dominant taxonomic units
- o Results of field transects
- o Descriptions of the environmental characteristics of both individual soil profiles and mapping units
- o Frosted, acetate overlays of mapping photos with mapping unit boundaries plotted on the overlays
- o Soil samples of typifying soil profiles for laboratory analysis
- o Description of the occurrence and density of plant species

The mapping unit boundaries from the mapping photos were transferred to clear overlays of the photo mylar quadrangle maps. Because of photo distortion in mountainous terrain, the information was transferred by viewing stereo photo pairs and placing the boundaries on corresponding landscape features noted on the topographic base.

After mapping unit boundaries were transferred to the quadrangle base, a conversion legend was created which placed each mapping unit into a sensitivity class.

HOW TO USE THIS REPORT

First, the user refers to the Index to Map Sheets to identify the map sheet that provides coverage of the area of interest.

Utilizing the map sheets, the user identifies the map unit symbol

assigned to a specific location. Once the map unit symbol is identified, the user refers to the Map Unit Description section of the appropriate soil survey report to find a characterization of the soils and landscape characteristics of the map unit.

More specific information regarding the components can be found in the section entitled Taxonomic Unit Descriptions.

REPORT ORGANIZATION

The soil survey reports which follow contain information on the 106,000 acres mapped under this effort. The mapping performed is presented separately for each National Park. Each report contains the following elements:

- Description of the Area
- Alphabetical List of Soil Taxonomic Units
- Classification Table of Taxonomic Units
- Taxonomic Unit Descriptions
- Descriptions of Map Units

Additional data, including chemical and physical characterization which is a basis for the assignment of sensitivity rankings, are included in Appendix B, Data Tables.

SOIL SURVEY OF
TUOLUMNE MEADOWS STUDY AREA
YOSEMITE NATIONAL PARK

DESCRIPTION OF THE AREA

LOCATION

The study area consists of about 43,000 acres in the east-central part of Yosemite National Park in the Sierra Nevada of California (Tuolumne Meadows 15' quadrangle and Mono Craters 15' quadrangle). It lies between the coordinates of latitude 37° 49' and 37° 57' north, and longitudes 119° 13' and 119° 30' west.

The area is bounded on the northwest and east by the park boundary that lies along the Sierra Crest between Tuolumne and Mono Counties, from White Mountain south to Kuna Peak. From White Mountain, the study area boundary runs approximately west-southwest along the ridge lines connecting Ragged Peak, Tuolumne Peak and southwest to the intersection of the ridgeline with the Mariposa County Line. It follows this county line for a short distance and continues south along a ridgeline to the Tioga Road (Highway 120) immediately southwest of Tenaya Lake. The southern boundary continues along the ridgelines connecting Tressidor, Echo, and Cathedral Peaks. It continues north a short way to Fairview Dome and Tuolumne Meadows. It follows Lyell Fork Creek for a distance and then continues along the ridgeline to Mammoth Peak and along the Kuna Crest to Kuna Peak, where it intersects the park boundary.

TERRAIN

The study area is primarily gently sloping to very steep alpine country lying just west of the Sierra Nevada Crest. Elevations

range from about 7900 feet at a point just below Tuolumne Falls, to more than 13,050 feet at the summit of Mount Dana on the Sierra Crest. The topography is predominantly complex and very bouldery; a result of extensive glaciation of the area. This glaciation has also served to carve the many peaks, lake basins and meadows, and dome-like rock structures that are so notable in the Yosemite area of the High Sierra.

GENERAL GEOLOGY

A large portion of the survey area is comprised of the massive granitic Tuolumne intrusive suite, much of which is overlain by a relatively thin mantle of glacial fill from the last Pleistocene episode. This acid intrusive granitic rock is mostly granodiorite, often characterized by large phenocrysts. At one time glacial ice covered much of the area below the higher peaks that are at elevations greater than about 11,000 feet. On the eastern margin of the survey area are metamorphosed volcanic and sedimentary rocks that were disrupted by the intrusion of granitic rocks of the Tuolumne Suite. The metasedimentary and metavolcanic rocks are mostly hornfels, local graywackes, and volcanic tuffs and flows.

VEGETATION

The natural vegetation of the study area is an expression of the upper reaches of the west side of the Sierra Nevada Crest. Below timberline, the coniferous forest is dominated by lodgepole pine with some mountain hemlock. Red fir and western white pine is found on some northerly slopes below 10,000 feet, with whitebark pine gradually replacing the lodgepole at elevations above 10,000 feet. The understory consists mostly of regenerating conifers, grasses, sedges, and scattered shrubs, most notably current and red mountain heather. The meadows support a wide variety of grasses,

sedges, and wildflowers, with lodgepole pine often encroaching around the margins. Higher alpine areas support mostly grasses, willows, and scattered white bark pine.

TABLE 1-Y

SOIL TAXONOMIC UNITS
(Alphabetical Order)

Tuolumne Meadows Study Area

Yosemite National Park

Aeric Cryaquepts, fine-loamy, mixed
Dystic Cryochrepts, coarse-loamy, mixed
Dystic Cryochrepts, loamy-skeletal, mixed
Lithic Cryochrepts, loamy, mixed
Lithic Cryochrepts, loamy-skeletal, mixed
Lithic Cryumbrepts, loamy, mixed
Lithic Xerumbrepts, loamy, mixed, frigid
Pachic Cryoborolls, loamy-skeletal, mixed
Typic Cryofluvents, coarse-loamy, mixed
Typic Cryofluvents, sandy-skeletal, mixed
Typic Cryumbrepts, loamy-skeletal, mixed
Typic Xerumbrepts, loamy-skeletal, mixed, frigid

TABLE 2-Y
CLASSIFICATION TABLE OF TAXONOMIC UNITS
Tuolumne Meadows Study Area
Yosemite National Park

ENTISOLS

Cryofluvents

Typic Cryofluvents, coarse-loamy, mixed
Typic Cryofluvents, sandy-skeletal, mixed

INCEPTISOLS

Cryaquepts

Aeric Cryaquepts, fine-loamy, mixed

Cryochrepts

Dystric Cryochrepts, coarse-loamy, mixed
Dystric Cryochrepts, loamy-skeletal, mixed
Lithic Cryochrepts, loamy, mixed
Lithic Cryochrepts, loamy-skeletal, mixed

Cryumbrepts

Typic Cryumbrepts, loamy-skeletal, mixed
Lithic Cryumbrepts, loamy, mixed

Xerumbrepts

Typic Xerumbrepts, loamy-skeletal, mixed, frigid
Lithic Xerumbrepts, loamy, mixed, frigid

MOLLISOLS

Cryoborolls

Pachic Cryoborolls, loamy-skeletal, mixed

TAXONOMIC UNITS OF THE TUOLUMNE MEADOWS STUDY AREA

DESCRIPTION OF TAXONOMIC UNITS

Aeric Cryaquepts, fine-loamy, mixed

This soil family consists of moderately deep soils forming in mixed alluvium and underlain by glacial till, or deep soils in recent alluvium. These soils are poorly drained and occur in kettles, depressions, and adjacent to drainageways on subalpine wet meadow areas. Slopes are 0 to 10 percent.

Typically, these soils have a thin dark surface layer, a gravelly to very gravelly loamy subsoil, underlain by a dense brittle gravelly hardpan of glacial till.

Following is a profile description of a representative pedon (7039-11) found in map unit 102 *Dystic Cryochrepts - Aeric Cryaquepts complex, 0 to 15 percent slopes*. It is located in upper Dana Meadows about 1 mile south-southeast of the Tioga Pass Entry Station of Yosemite National Park; slope is 5 percent north; elevation is 9850 ft.; vegetation is grasses and sedges (colors are for dry soil unless otherwise noted):

A1--0 to 3 inches; dark grayish brown (10YR 4/2) silt loam, black (10YR 2/1) moist; massive; slightly hard, friable, slightly sticky and nonplastic; many very fine, fine, and few medium roots; clear smooth boundary.

A2--3 to 9 inches; grayish brown (10YR 5/2) silt loam, very dark brown (10YR 2/2) moist; weak fine sub-angular blocky structure; slightly hard, friable,

slightly sticky and slightly plastic; many very fine, fine, and few medium roots; 5 percent pebbles; clear smooth boundary.

2Bw1--9 to 16 inches; yellowish brown (10YR 5/4) very gravelly loam, dark yellowish brown (10YR 3/4) moist; few fine prominent mottles of dark yellowish brown (moist); weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine, fine, and medium roots; 35 percent pebbles and 5 percent cobbles; abrupt smooth boundary.

2Bw2--16 to 24 inches; light yellowish brown (2.5Y 6/4) gravelly loam, olive brown (2.5Y 4/4) moist; common medium prominent mottles of dark yellowish brown (moist); weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine, fine, and few medium roots; 20 percent pebbles and 5 percent cobbles; abrupt smooth boundary.

2Bx1--24 to 30 inches; light yellowish brown (2.5Y 6/4) dense and brittle hardpan that parts to gravelly loam, light olive brown (2.5Y 5/4) moist; many medium prominent mottles of yellowish brown (moist); massive; hard, firm, slightly sticky and slightly plastic; few very fine roots; 15 percent pebbles and 5 percent cobbles; abrupt smooth boundary.

2Bx2--30 to 60 inches; pale yellow (2.5Y 7/4) dense hardpan parting to gravelly sandy loam, light olive brown (2.5Y 5/4) moist; common medium prominent

mottles of light yellowish brown (moist); massive;
hard, very firm, nonsticky and nonplastic; 25
percent pebbles and 5 percent cobbles.

Remarks: The particle-size control section averages 18 to 27
percent clay and 15 to 35 percent rock fragments. Depth to hardpan
is 20 to 40 inches

Dystric Cryochrepts, coarse-loamy, mixed

This soil family commonly consists of deep, moderately well to well
drained soils that formed in granitic colluvium and glacial till,
with an influential component of volcanic ash in the solum. This
soil is most often found on concave mountain benches, footslopes,
and between joints in association with granitic rock outcrop. Less
commonly, this family consists of moderately deep soils on glacial
moraines underlain by a dense glacial till hardpan or rhyolitic
tuff. Slopes are complex and range from 5 to 25 percent.

Typically the soils have a thin dark surface over a moderately
developed subsoil characterized by a light bulk density.

Following is a profile description of a representative pedon
(7228-5) found in the map unit *11 Jointed granitic outcrop - Lithic
Cryumbrepts - Dystric Cryochrepts complex, 5 to 30 percent slopes*.
It is located about 0.6 miles northwest of Tuolumne Falls; slope
is 7 percent north; elevation is 8400 ft.; vegetation is mainly
lodgepole pine with mountain hemlock, grass, sedge, ribes, and
mountain heather (colors are for dry soil unless otherwise noted):

Oi--3 inches to 0; slightly decomposed needles, twigs,
and bark.

A--0 to 5 inches; brown (10YR 5/3) fine sandy loam, very dark brown (10YR 2/2) moist; weak fine and medium granular structure; soft, very friable, nonsticky and nonplastic; common very fine, fine, and few medium roots; clear wavy boundary.

Bw1--5 to 13 inches; brown (7.5YR 5/4) sandy loam, very dark brown (7.5YR 3/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine, and few medium roots; gradual wavy boundary.

Bw2--13 to 24 inches; brown (7.5YR 5/4) sandy loam, very dark brown (7.5YR 3/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few very fine, fine, and medium roots; 5 percent pebbles; gradual wavy boundary.

Bw3--24 to 60 inches; reddish yellow (7.5YR 6/6) cobbly sandy loam, strong brown (7.5YR 4/6) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few fine and medium roots; 10 percent pebbles and 20 percent cobbles.

Remarks: The particle-size control section averages 5 to 35 percent rock fragments. Textures are fine sandy loam and sandy loam.

Dystric Cryochrepts, loamy-skeletal, mixed

In general, this soil family occurs on more northerly aspects and at higher elevations in the survey area than Typic Cryumbrepts (loamy-skeletal), but they are often associated in complex mapping units. Loamy-skeletal Dystric Cryochrepts commonly are well drained, moderately deep soils. They formed primarily in colluvium and residuum from granitic rocks, granitic glacial till, and are influenced by volcanic ash in the solum. However, in the Parker Pass Creek area, both the till and the colluvium has a mixed source of granitic, metavolcanic, and metasedimentary rock. A dense brittle hardpan or granodiorite bedrock commonly occurs between 20 to 40 inches. Less commonly, the till is unconsolidated or bedrock is at a depth of 40 to greater than 60 inches, especially on steeper colluvial soils. The surface is almost always very stony to extremely bouldery. Slopes are complex and range from 5 to 75 percent.

Typically the soils have a thin, dark, fine sandy loam surface layer. A moderately developed very gravelly to very stony subsoil with brighter colors overlies a dense till hardpan, or in some cases, granodiorite.

Following is a profile description of a representative pedon (7038-1) found in the map unit *100 Dystric Cryochrepts, 15 to 45 percent slopes*. It is located approximately 1.5 miles northwest of Mammoth Peak; slope is 32 percent north; elevation is 9800 ft.; vegetation is lodgepole pine with mountain hemlock, grass, sedge, and ribes (colors are for dry soil unless otherwise noted):

Oi--1 in to 0; slightly decomposed needles, leaves, and twigs.

A--O to 6 inches; dark grayish brown (10YR 4/2) cobbly fine sandy loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, and common medium roots; 5 percent stones, 15 percent cobbles, and 10 percent pebbles; clear wavy boundary.

Bw1--6 to 11 inches; yellowish brown (10YR 5/4) very stony sandy loam, dark brown (7.5YR 3/4) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, common medium and coarse roots; 20 percent stones, 15 percent cobbles, and 15 percent pebbles; abrupt wavy boundary.

Bw2--11 to 25 inches; light brown (7.5YR 6/4) extremely stony sandy loam, reddish brown (5YR4/4) moist; weak and moderate fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine, common fine and medium roots; 30 percent stones, 15 percent cobbles, and 15 percent pebbles; clear wavy boundary.

2BC--25 to 37 inches; light yellowish brown (2.5Y 6/4) and (10YR 6/4) very gravelly fine sandy loam, olive brown (2.5Y 4/4) and dark yellowish brown (10YR-4/4) moist; common black organic staining on peds; weak fine and medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common very fine and fine roots; 10 percent cobbles and 30 percent pebbles; abrupt smooth boundary.

2Cr--37 to 60+ inches; light yellowish brown (2.5Y 6/4) dense hardpan parting to very gravelly sandy loam, olive brown (2.5Y 4/4) moist; common black organic staining on peds; massive; firm, friable, nonsticky and nonplastic; common very fine and fine roots matting on top of horizon; 5 percent cobbles and 35 percent pebbles.

Remarks: The particle-size control section averages 35 to 60 percent rock fragments. Textures are fine sandy loam or sandy loam throughout. A discontinuous alluvial surface horizon is present in some pedons.

Lithic Cryochrepts, loamy, mixed

This soil family is found throughout the survey area and always associated with rock outcrop. It consists of shallow and very shallow, well drained soils over mostly granodiorite. In the Parker Pass Creek area the bedrock may be metamorphic. These soils are formed in colluvium and residuum, with the addition of slope-wash material and volcanic ash. They occur on glacially scoured basins, cirques, mountain sideslopes, and around rock outcrops, primarily on benches, ledges, and rock joints and crevices. Slopes are complex and range from 5 to 75 percent.

Typically these soils have a thin dark surface with a slightly developed subsoil over land granodiorite.

Following is a profile description of a representative pedon (7121-1) found in map unit *80 Lithic Cryochrepts - Jointed granitic outcrop - Typic Cryumbrepts complex, 5 to 30 percent slopes*. It is located about 0.5 miles northwest of Soda Springs; slope is 8 percent northeast; elevation is 8700 feet; vegetation is sedge and

grass with a 5 percent canopy of lodgepole pine (colors are for dry soil unless otherwise noted):

A--0 to 4 inches; brown (10YR 5/3) gravelly sandy loam, very dark grayish brown (10YR 3/2) moist; weak very fine granular structure; soft, very friable, non-sticky and nonplastic; many very fine and fine roots; 5 percent cobbles and 20 percent pebbles; clear wavy boundary.

Bw--4 to 15 inches; yellowish brown (10YR 5/4) gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; 5 percent cobbles and 25 percent pebbles; abrupt smooth boundary.

R--15+ inches; hard granodiorite.

Remarks: The particle-size control section averages 0 to 35 percent rock fragments. Depth to bedrock ranges from 5 to 20 inches.

Lithic Cryochrepts, loamy-skeletal, mixed

This soil family consists of shallow and very shallow well to somewhat excessively drained soils forming in colluvium and residuum from metamorphic rocks. The soils occur on mountain ridges and sideslopes. Slopes are 45 to 75 percent.

Typically, these soils have a thin dark surface layer, a weakly developed subsoil of extremely flaggy and extremely channery coarse sandy loam, overlying metavolcanic bedrock.

Following is a profile description of a representative pedon (7041-4) found in map unit 70 *Metamorphic talus - Lithic Cryochrepts - Jointed metamorphic outcrop complex, 45 to 75 percent slopes*. It is located on Gaylor Peak about 0.6 miles northwest of the Tioga Pass Entry Station of Yosemite National Park; slope is 55 percent; elevation is 10,800 feet; vegetation is widely scattered whitebark pine, mountain heather, and sedges (colors are for dry soil unless otherwise noted):

Oi--1/4 inch to 0; slightly decomposed needles.

A--0 to 4 inches; brown (10YR 5/3) extremely flaggy coarse sandy loam, very dark grayish brown (10YR 3/2) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; 25 percent flags, 20 percent channers, and 20 percent pebbles; abrupt wavy boundary.

Bw--4 to 15 inches; light yellowish brown (10YR 6/4) extremely channery coarse sandy loam, dark yellowish brown (10YR 4/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine, and medium roots; 10 percent flags, 30 percent channers, and 30 percent pebbles; abrupt irregular boundary.

R--15 to 17+ inches; fractured, hard metavolcanic rock.

Remarks: Particle-size control section commonly averages 60 to 75 percent rock fragments. Depth to bedrock is 7 to 20 inches.

Lithic Cryumbrepts, loamy, mixed

This soil family consists of well to somewhat excessively drained shallow and very shallow soils. They formed in slope wash and colluvium and residuum from granitic rocks, with an influence of volcanic ash. They occur on benches, ledges, rock fissures, and steep slopes in complex with jointed granitic rock outcrop. Slopes are 10 to 55 percent.

Typically the soils have a dark surface layer and a weakly developed subsoil over hard granodiorite.

Following is a profile description of a representative pedon (7297-1) found in the map unit *11 Jointed granitic outcrop - Lithic Cryumbrepts - Dystric Cryochrepts complex, 5 to 30 percent slopes*. It is located about 1 mile northwest of Tenaya Lake, approximately 0.5 miles north on Murphy Creek trail and 0.5 miles west of the creek; slope is complex 10 percent north-northwest; elevation is 8400 feet; vegetation is sparse lodgepole pine and grass (colors are for dry soil unless otherwise noted):

Oi--1 inch to 0; slightly decomposed pine litter.

A1--0 to 2 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; 5 percent pebbles; abrupt smooth boundary.

A2--2 to 9 inches; grayish brown (10YR 5/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; soft,

very friable, nonsticky and nonplastic; many very fine, fine, medium, and coarse roots; 5 percent pebbles; abrupt smooth boundary.

Bw--9 to 18 inches; yellowish brown (10YR 5/4) gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine and medium subangular blocky structure; many very fine, fine, common medium, and few coarse roots; 20 percent pebbles; abrupt irregular boundary.

R--18+ inches; hard fractured granodiorite.

Remarks: The particle-size control section averages 15 to 35 percent rock fragments. It should be noted, however, that there are dissimilar shallow soils that average more than 35 percent rock fragments, but occur in a pattern too complex to map separately.

Lithic Xerumbrepts, loamy, mixed, frigid

This soil family consists of shallow, well drained soils forming in colluvium and residuum over granodiorite. They occur on southerly aspects on glacially quarried sideslopes of granitic mountains and are associated with rock outcrop. Slope ranges from 30 to 60 percent.

Typically, the soils have a dark surface layer and brighter colored subsoil over granodiorite.

Following is a profile description of a representative pedon (7228-8) found in the map unit *60 Typic Xerumbrepts - Lithic Xerumbrepts - Jointed granitic outcrop complex, 30 to 60 percent slopes*. Traveling approximately 1 mile west along Highway 120 from the

southwest corner of Tuolomne Meadows, it is located north an upslope about 0.25 miles from the road; slope is 30 percent southeast; elevation is 8700 feet; vegetation is manzanita with scattered western juniper and lodgepole pine (colors are for dry soil unless otherwise noted):

A1--0 to 3 inches; grayish brown (10YR 5/2) gravelly fine sandy loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; 15 percent pebbles; clear wavy boundary.

A2--3 to 9 inches; grayish brown (10YR 5/2) gravelly fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine, and medium roots; 5 percent cobbles and 15 percent pebbles; abrupt wavy boundary.

Bw--9 to 12 inches; yellowish brown (10YR 5/4) cobbly fine sandy loam, dark yellowish brown (10YR 3/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine, and medium roots; 15 percent cobbles and 15 percent pebbles; abrupt irregular boundary.

R--12+ inches; hard fractured granodiorite.

Remarks: The particle-size control section averages 15 to 35 percent rock fragments.

Miscellaneous land type

Pachic Cryoborolls, loamy-skeletal, mixed

This soil family consists of deep, moderately well to somewhat poorly drained soils forming in colluvium. They occur on steep mountain sideslopes near treeline. They are found in concave positions and are associated with drainages, springs, seeps, and late spring snow melt. Slope ranges from 30 to 70 percent.

Typically the soils have a deep dark surface layer and lighter subsoil.

Following is a profile description of a representative pedon (7038-2) found in the map unit *40 Pachic Cryoborolls - Dystric Cryochrepts - Rock outcrop complex, 30 to 70 percent slopes*. It is located on the north face approximately 1 mile northwest of Mammoth Peak; slope is 40 percent north; elevation is 10,300 feet; vegetation is grass, willow, ribes, with scattered mountain hemlock and whitebark pine (colors are for dry soil unless otherwise noted):

Oi--2 inches to 0; sod mat with leaves, dead grass.

A1--0 to 9 inches; dark gray (10YR 4/1) very stony fine sandy loam, black (10YR 2/1) and very dark brown

(10YR 2/2) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, common medium, and coarse roots; 15 percent stones, 15 percent cobbles, and 10 percent pebbles; clear smooth boundary.

A2--9 to 22 inches; dark grayish brown (10YR 4/2) extremely stony sandy loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, and common medium roots; 30 percent stones, 15 percent cobbles, 15 percent pebbles; clear wavy boundary.

Bw--22 to 60 inches; yellowish brown (10YR 5/4) very cobbly sandy loam, dark yellowish brown (10YR 3/4) moist; weak to moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; 5 percent stones, 10 percent cobbles, and 30 percent pebbles.

Remarks: The particle-size control section averages 35 to 60 percent rock fragments, and twelve to 25 percent clay. Textures are loam, fine sandy loam, and sandy loam, and may be very gravelly, very cobbly, very channery, very stony, or extremely stony. Mottles below 30 inches are common.

Typic Cryofluvents, coarse-loamy, mixed

This soil family consists of very deep, poorly to somewhat poorly drained soils forming in recent alluvial valley fill material. Commonly, these soils are underlain by sand and gravel derived from

glacial outwash deposits. It is found in the wet meadow areas (Tuolomne and Dana), and along streams and drainages. Slopes are 0 to 5 percent.

Typically, the soils have a dark surface layer moderately high in organic matter. Below the surface layer, layers are stratified with medium to coarse textures.

Following is a profile description of a representative pedon (7228-1) found in the map unit *110 Typic Cryofluvents, 0 to 5 percent slopes*. It is located in a meadow adjacent to the Tuolomne River about 1.25 miles upstream (southeast) from Tuolomne Falls; slope is 1 percent northwest; elevation is 8350 feet; vegetation is grass, sedge, forbs (colors are for dry soil unless otherwise noted):

Oi--1/4 to 0 inches; partially decomposed grass and leaves of forbs.

A--0 to 8 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; clear smooth boundary.

AC--8 to 18 inches; light brownish gray (10YR 6/2) fine sandy loam, dark brown (10YR 3/3) moist; few fine prominent mottles of strong brown (moist); weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; gradual smooth boundary.

C1--18 to 35 inches; light brownish gray (10YR 6/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; common fine prominent mottles of strong brown (moist); weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few very fine and fine roots; abrupt wavy boundary.

C2--35 to 60 inches; multicolored gravelly coarse sand; brown iron stains on pebbles; single grained; loose, nonsticky and nonplastic; few very fine and fine roots; 25 percent pebbles.

Remarks: Depth to sand and gravel ranges from 32 to greater than 60 inches. Buried surface horizons and thin layers of volcanic ash are common.

Typic Cryofluvents, sandy-skeletal, mixed

This soil family consists of very deep, somewhat poorly to poorly drained soils forming in recent alluvial material overlying sand and gravel. It is found in wet meadow areas, along streams and drainages, and in low depressions between ridges of glacial moraines. Slopes are 0 to 3 percent.

Typically, the surface and subsurface layers are dark with medium to moderately coarse textures. The substratum is stratified very gravelly or very cobbly loamy sand to extremely gravelly coarse sand.

Following is a profile description of a representative pedon (7039-4) found in the map unit 51 *Typic Cryumbrepts - Typic Cryofluvents complex*, 0 to 20 percent slopes. It is located in

Dana Meadows about 2 miles south of the Tioga Pass entry station of Yosemite National Park; slope is 1 percent west; elevation is 9350 ft.; vegetation is sedge and grass (colors are for dry soil unless otherwise noted):

Oi--4 to 3 inches; sod root mat of grass and sedge.

Oa--3 inches to 0; very decomposed sapric material.

A1--0 to 2 inches; grayish brown (10YR 5/2) silt loam, dark brown (7.5YR 3/2) moist; moderate fine and medium granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; abrupt smooth boundary.

A2--2 to 6 inches; brown (10YR 5/3) silt loam, dark brown (10YR 3/3) moist; moderate fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; abrupt smooth boundary.

C1--6 to 11 inches; yellowish brown (10YR 5/4) and light gray (10YR 7/2) loam, dark yellowish brown (10YR 3/4) and grayish brown (10YR 5/2) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; 10 percent pebbles; clear smooth boundary.

C2--11 to 17 inches; yellowish brown (10YR 5/4) very cobbly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; few very

fine and fine roots; 25 percent cobbles and 25 percent pebbles; clear wavy boundary.

C3--17 to 60 inches; yellowish brown (10YR 5/4) extremely cobbly loamy sand, dark yellowish brown (10YR 3/4) moist; single grained; loose, nonsticky and nonplastic; few very fine roots; 25 percent cobbles and 60 percent pebbles.

Remarks: Depth to sand and gravel is 15 to 25 inches. Many pedons have a buried surface horizon. Water table at 17 inches.

Typic Cryumbrepts, loamy-skeletal, mixed

This soil family is the most well represented family in the survey area, and is a component of several map units. Commonly, these are moderately deep, moderately well drained soils forming in granitic colluvium and glacial till, with a component of volcanic ash, overlying a dense, compact till hardpan. They are on ridges and sideslopes of lateral and ground moraines. In some cases, similar soils are underlain by granodiorite or localized rhyolitic tuff where glacial deposition is thin or has been eroded away. Less commonly, these soils are deep and well drained, forming in similar materials, but often characterized by a greater component of volcanic ash. They occur on steep colluvial mountain sideslopes and somewhat concave areas of moraines on benches, toeslopes, and along drainages. In the Parker Pass Creek area, similar deep soils are forming in colluvium and till of mixed granitic and metamorphic origin. slope ranges from 5 to 65 percent.

Typically the soils have a dark surface layer. The subsoil is weakly to moderately well developed with brighter colors, overlying a dense till hardpan.

Following is a profile description of a representative pedon (7062-3) found in the map unit 52 *Typic Cryumbrepts - Dystric Cryochrepts complex*, 5 to 30 percent slopes. It is located on Moraine Flat, approximately 1.2 miles north of Highway 120, and just west of the Gaylor Lakes Trail; slope is 16 percent south-southeast; elevation is 9800 feet; vegetation is lodgepole pine, grass, and sedge (colors are for dry soil unless otherwise noted):

Oi--1 inch to 0; slightly decomposed grass, needles, and twigs.

Al--0 to 4 inches; grayish brown (10YR 5/2) very stony sandy loam, very dark grayish brown (10YR 3/2) moist; moderate very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; 15 percent stones, 10 percent cobbles, and 10 percent pebbles; clear wavy boundary.

A2--4 to 13 inches; brown (10YR 5/3) very stony fine sandy loam, dark brown (10YR 3/3) moist; moderate very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, and common medium roots; 20 percent stones, 20 percent cobbles, and 15 percent pebbles; clear wavy boundary.

2Bw--13 to 29 inches; yellowish brown (10YR 5/4) extremely stony sandy loam, dark yellowish brown (10YR 3/6) moist; moderate medium and fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine and medium roots; 25 percent stones, 20 percent cobbles, 15 percent pebbles; abrupt wavy boundary.

2Bx--29 to 41+ inches; brownish yellow (10YR 6/6) dense, brittle till parting to gravelly sandy loam, dark yellowish brown (10YR 4/6) moist; common medium prominent mottles of strong brown and light olive brown; massive; hard, firm, nonsticky and nonplastic; few very fine roots; 5 percent cobbles and 20 percent pebbles.

Remarks: The particle-size control section averages 35 to 65 percent rock fragments. Surface and subsurface textures range from loam to sandy loam and may be gravelly to extremely stony sandy loams or coarse sandy loams.

Typic Xerumbrepts, loamy-skeletal, mixed, frigid

This soil family consists of moderately deep, well drained soils formed in colluvium, till, and rhyolitic tuff over granodiorite. They occur on southerly aspects on slightly concave, mid and lower sideslopes of glacially quarried granitic mountains. Slopes range from 30 to 60 percent.

Typically, the soils have a dark surface and a somewhat developed lighter subsoil over a paralithic contact of hard rhyolitic tuff.

Following is a profile description of a representative pedon (7263-2) found in map unit 60 *Typic Xerumbrepts - Lithic Xerumbrepts - Jointed Granitic Outcrop Complex, 30 to 60 percent slopes*. It is located upslope from Highway 120 approximately 1 mile northeast of the north end of Tenaya Lake; slope is 50 percent southeast; elevation is 8500 feet; vegetation is mainly chinquapin with western juniper, Jeffrey pine, lodgepole pine, ribes, sagebrush, manzanita, and fescue (colors are for dry soil unless otherwise noted):

Oi--2 inches to 0; slightly and moderately decomposed leaves, twigs, and needles.

A1--0 to 7 inches; dark gray (10YR 4/1) cobbly sandy loam, very dark brown (10YR 2/2) moist; weak very fine and fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; 15 percent cobbles; clear wavy boundary.

A2--7 to 10 inches; dark grayish brown (10YR 4/2) cobbly sandy loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, and medium roots; 10 percent cobbles and 10 percent pebbles; abrupt wavy boundary.

Bw1--10 to 17 inches; yellowish brown (10YR 5/6) very cobbly sandy loam, dark brown (7.5YR 3/4), moist; moderate fine and medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common very fine, fine, medium, and coarse roots; 20 percent cobbles and 20 percent pebbles; abrupt wavy boundary.

Bw2--17 to 24 inches; yellowish brown (10YR 5/4) very cobbly fine sandy loam, dark yellowish brown (10YR-3/4) moist; moderate fine and medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common medium, coarse, few fine, and very fine roots; 15 percent cobbles and 25 percent pebbles; abrupt irregular boundary.

2Cr--24 to 32+ inches; hard, ashy tuff.

Remarks: The particle-size control section averages 35 to 60 percent rock fragments. Textures are fine sandy loam and sandy loam.

TABLE 3-Y

MAP UNIT LEGEND
TUOLUMNE MEADOWS STUDY AREA
Yosemite National Park

<u>SYMBOL</u>	<u>MAP UNIT NAME</u>
10	Jointed granitic outcrop - Lithic Cryochrepts complex, 15 to 45 percent slopes.
11	Jointed granitic outcrop - Lithic Cryumbrepts -Dystric Cryochrepts complex, 5 to 30 percent slopes.
12	Jointed granitic outcrop - granitic talus - Lithic Cryochrepts complex, 45 to 130 percent slopes.
20	Unjointed granitic outcrop.
30	Lake.
40	Pachic Cryoborolls - Dystric Cryochrepts - Rock outcrop complex, 30 to 70 percent slopes.
50	Typic Cryumbrepts - Dystric Cryochrepts - Typic Cryofluvents complex, 0 to 35 percent slopes.
51	Typic Cryumbrepts - Typic Cryofluvents complex, 0 to 20 percent slopes.
52	Typic Cryumbrepts - Dystric Cryochrepts complex, 5 to 30 percent slopes.
53	Typic Cryumbrepts, 25 to 55 percent south slopes.
54	Typic Cryumbrepts, 15 to 45 percent north slopes.
55	Typic Cryumbrepts - Lithic Cryochrepts - Jointed granitic outcrop complex, 5 to 30 percent slopes.
60	Typic Xerumbrepts - Lithic Xerumbrepts - Jointed granitic outcrop complex, 30 to 60 percent slopes.
70	Metamorphic talus - Lithic Cryochrepts - Jointed metamorphic outcrop complex, 45 to 75 percent slopes.

MAP UNIT LEGEND, Continued

<u>SYMBOL</u>	<u>MAP UNIT NAME</u>
71	Metamorphic outcrop - Lithic Cryochrepts - Typic Cryumbrepts complex, 15 to 75 percent slopes.
72	Metamorphic outcrop - metamorphic talus - Typic Cryumbrepts complex, 35 to 130 percent slopes.
80	Lithic Cryochrepts - Jointed granitic outcrop - Typic Cryumbrepts complex, 5 to 30 percent slopes.
81	Lithic Cryumbrepts - Dystric Cryochrepts - Jointed granitic outcrop complex, 30 to 55 percent slopes.
82	Lithic Cryochrepts - Jointed granitic outcrop complex, 5 to 30 percent slopes.
90	Dystric Cryochrepts - Typic Cryumbrepts - metamorphic talus complex, 45 to 75 percent slopes.
91	Dystric Cryochrepts, 15 to 60 percent slopes.
100	Dystric Cryochrepts, 15 to 45 percent slopes.
101	Dystric Cryochrepts - Jointed granitic outcrop -Lithic Cryochrepts complex, 40 to 75 percent slopes.
102	Dystric Cryochrepts - Aeric Cryaquepts complex, 0 to 15 percent slopes.
110	Typic Cryofluvents, 0 to 5 percent slopes.
W	Lakes and Other Water Bodies

MAP UNITS OF THE TUOLOMNE MEADOW STUDY AREA

DESCRIPTIONS OF MAP UNITS

10 Jointed granitic outcrop - Lithic Cryochrepts complex, 15 to 45 percent slopes

The mapping unit is found on glacially quarried cirque basins and valley floors, and footslopes and toeslopes of mountains. The rock is predominantly granodiorite of Cathedral Peak.

This map unit is on sideslopes of Kuna Crest, Ragged Peak, and the vicinity of Cathedral Peak and Medicott Dome. It is composed of 9 delineations.

80% Jointed granitic outcrop

15% Lithic Cryochrepts, loamy, mixed; 20 to 45 percent slopes.

The Lithic Cryochrepts are shallow, well drained soils that occur in joints, crevices, and on ledges associated with the rock outcrop. It formed in colluvium and residuum from granodiorite with an influence of volcanic ash. Vegetative cover is sparse, consisting of clumps and individual trees of whitebark pine with some lodgepole pine and mountain hemlock. Canopy cover is 10 percent or less.

Included in this unit are:

4% Lithic Cryorthents, loamy-skeletal, mixed; 20 to 45 percent slopes

1% Cryofluvents, 5 to 15 percent slopes

11 Jointed granitic outcrop - Lithic Cryumbrepts - Dystric Cryochrepts complex, 5 to 30 percent slopes

The map unit occurs on topographically complex glacially scoured mountain footslopes and valley floors. The parent rock is predominantly Half-Dome and Cathedral Peak granodiorite. The rock outcrop is prominent and steep.

This map unit has 4 delineations near Murphy Creek, Tuolumne Falls, and Medicott Dome.

- 45% Jointed granitic outcrop
- 25% Lithic Cryumbrepts, loamy, mixed; 10 to 30 percent slopes
- 20% Dystric Cryochrepts, coarse-loamy, mixed; 5 to 15 percent slopes

The Lithic Cryumbrepts are shallow, well-drained soils occupying benches, ledges and crevices between rock joints. The Dystric Cryochrepts typically are deep moderately well drained soils found in concave sideslopes between widely spaced joints. In addition, there are moderately deep well drained soils in slightly higher, more convex positions. These soils formed in volcanic ash and granitic colluvium and residuum.

Vegetation is predominantly lodgepole pine with some mountain hemlock and an occasional whitebark pine. The canopy cover varies from 5 to 10 percent on Lithic Cryumbrepts to 15 to 25 percent on Dystric Cryochrepts. The understory contains grasses, sedges, ribes, phlox, and red mountain heather.

Included in this unit are:

- 8% Skeletal soils-Lithic Cryumbrepts and Dystric Cryochrepts that contain more than 35 percent rock fragments and are loamy-skeletal
- 2% Cryofluvents, 0 to 10 percent slopes

12 Jointed granitic outcrop - granitic talus - Lithic Cryochrepts complex, 45 to 130 percent slopes

The map unit is found on crests and ridges of mountains and headwalls of cirque basins. It is near or above treeline. The rock is granodiorite of the Cathedral Peak, Half Dome, and Kuna Crest formations.

This map unit has 4 delineations that occur on higher elevations near Ragged Peak, White Mountain, Mammoth Peak, and Kuna Crest.

- 50% Jointed granitic outcrop
- 20% Granitic talus
- 15% Lithic Cryochrepts, loamy, mixed, 45 to 75 percent slopes

The Lithic Cryochrepts are shallow, well-drained soils in joints, crevices, and on ledges.

Vegetation cover is sparse or non-existent. Stunted whitebark pine and heather occupy soil portions of this unit.

Included in this unit are:

- 5% Typic Cryorthents, sandy-skeletal, mixed, 30 to 50 percent slopes.

- 5% Cryaquepts
- 5% Felsenmeer

20 Unjointed granitic outcrop

This miscellaneous map unit consists of at least 80 percent exposed outcrops of granite or granodiorite with a spacing of 100 meters or more between vertical joints that are 2 meters or greater in depth. Sheet jointing parallel to the surface is common, as is evidence of glacial polish.

Included in this unit are:

- 10% Jointed granitic outcrop
- 5% Lithic Cryochrepts, loamy, mixed
- 5% Dystric Cryochrepts, loamy, mixed

The latter two inclusions support sparse clumps and stands of lodgepole and whitebark pine.

Examples of this unit are Pywiak, Polly, and Medicott Domes.

40 Pachic Cryoborolls - Dystric Cryochrepts - Jointed rock outcrop complex, 30 to 70 percent slopes

This map unit occurs on steep glaciated shoulders and backslopes of mountains near treeline. The unit is often characterized by avalanche chutes, debris flows, rock slides, seeps, and large boulders. There are 7 delineations near Mammoth Peak, Gaylor Lakes, and northeast of the Kuna Crest. The first two areas have soils dominated by granitic rocks. The latter area has soils influenced by granitic and metamorphic rocks.

- 45% Pachic Cryoborolls, loamy-skeletal, mixed, 30 to 60 percent slopes
- 20% Dystric Cryochrepts, loamy-skeletal, mixed, 35 to 70 percent slopes
- 15% Jointed rock outcrop

The Pachic Cryoborolls are deep, moderately well to somewhat poorly drained soils forming in colluvium. Slopes on the unit are complex and these soils tend to occupy concave positions that are both parallel and perpendicular to slope contour. The Dystric Cryochrepts are deep and moderately deep, well drained soils formed in colluvium and residuum on mostly convex slopes.

Included in this unit are:

- 13% Miscellaneous areas of talus, avalanche and landslide debris, rubbleland, and felsenmeer
- 5% Lithic Cryochrepts, loamy-skeletal, mixed
- 2% Poorly drained Cryofluvents and seeps

50 Typic Cryumbrepts - Dystric Cryochrepts - Typic Cryofluvents complex, 0 to 35 percent slopes

The map unit occurs on benched, bouldery sideslopes of moraines and valley floors. There are 4 delineations in the western part of the survey area.

- 50% Typic Cryumbrepts, loamy-skeletal, mixed, 10 to 35 percent slopes
- 20% Dystric Cryochrepts, coarse-loamy, mixed, 5 to 25 percent slopes
- 15% Typic Cryofluvents, coarse-loamy, mixed, 0 to 10 percent slopes.

The Typic Cryumbrepts are commonly deep, well and moderately well drained soils forming in granitic colluvium and glacial till. They are found on mainly north to east facing sideslopes of moraines on slightly concave to smooth slopes. Less commonly, they are moderately deep to granodiorite around rock outcrops. The Dystric Cryochrepts have a notable volcanic ash influence mixed with granitic colluvium. These soils are well to moderately well drained, deep or moderately deep, often overlying a dense till or rhyolitic tuff. They are found on benches and lower sideslopes of moraines adjacent to the valley floor. The Typic Cryofluvents are commonly somewhat poorly drained, deep soils forming in finer recent alluvium over older, coarse glacial outwash. These soils are found on valley floors and drainageways.

Overstory vegetation is predominantly lodgepole pine throughout the map unit, especially on the Typic Cryofluvents. However, western white pine, red fir, and mountain hemlock are often well represented on the Typic Cryumbrepts and Dystric Cryochrepts. Below a good canopy cover of the latter two soils, the understory is often sparse grass, sedge, and ribes. Typic Cryofluvents have an understory of sedges, grass, ribes, geraniums, and azaleas.

Included in this unit are:

- 5% Jointed granitic outcrop
- 3% Granitic talus (especially below Tenaya Peak)
- 2% Wet meadow areas
- 5% Typic Cryofluvents, sandy-skeletal, mixed, 0 to 3 percent slopes

51 Typic Cryumbrepts - Typic Cryofluvents complex, 0 to 20
percent slopes

The map unit is found on very stony to extremely bouldery ground moraines of glacially scoured valleys and footslopes of granitic mountains. The morainal deposits have complex, hilly topography commonly with an east-west orientation of ridges. In between morainal ridges are concave areas, mostly trending the same direction, that contain kettles, small wet meadows, drainageways, and old outwash terraces that contain a variety of soils. Small lakes, ponds, and scoured granitic outcrops are also representative. There are 12 delineations of this unit, many of which are found on Moraine Flat and the lower end of Dana Meadows.

Included in this unit are:

- 65% Typic Cryumbrepts, loamy-skeletal, mixed, 5 to 20 percent slopes
- 15% Typic Cryofluvents, coarse-loamy and sandy-skeletal, mixed, 0 to 8 percent slopes

The Typic Cryumbrepts are moderately deep, moderately well and well drained soils forming in bouldery glacial till with an influence of volcanic ash in the upper solum. These soils are commonly underlain by a dense, weakly brittle hardpan or localized material from rhyolitic tuff. Less commonly, they are underlain by granodiorite. This occurs on ridges and shoulders where morainal deposits are thin, and in areas where morainal material has been eroded away, such as along streams and channels. The Typic Cryofluvents are very deep, somewhat poorly and poorly drained soils forming in Holocene alluvium, sometimes underlain by glacial outwash.

Vegetation is predominantly uneven-aged lodgepole pine with occasional mountain hemlock on the morainal Typic Cryumbrepts. The understory is grass, sedges, and ribes. Occupying the wet meadows of the Typic Cryofluvents are a variety of grasses, sedges, and hydrophilic plants with marginal encroachments of lodgepole pine.

Included in this unit are:

- 5% Dystric Cryochrepts, loamy-skeletal, mixed, 10 to 25 percent slopes
- 5% Granitic outcrop and associated shallow soils
- 5% Humic and Aeric Cryaquepts, fine-loamy, mixed, 0 to 3 percent slopes
- 3% Aquic Cryumbrepts, loamy-skeletal, mixed, 2 to 8 percent slopes
- 2% Ephemeral ponds and intermittent streams

Dystric Cryochrepts are found primarily on north slopes of moraines and on concave benches with a significant volcanic ash deposit. Humic and Aeric Cryochrepts occupy depressions (kettles that are often ponded in spring) and areas adjacent to ponds. Humic Cryaquepts are like Aeric Cryaquepts except they have grayer colors throughout the profiles. Aquic Cryumbrepts are found in small grassy areas between morainal ridges, and along toeslopes between moraines and larger wet meadows. Aquic Cryumbrepts are wetter than Typic Cryumbrepts.

52 Typic Cryumbrepts - Dystric Cryochrepts complex, 5 to 30
percent slopes

This map unit is on very stony to extremely bouldery moraines with complex benched, dissected, hilly topography. There are 4 delineations found on Moraine Flat and west of Cathedral Peak.

65% Typic Cryumbrepts, loamy-skeletal, mixed, 5 to 30
percent slopes

15% Dystric Cryochrepts, loamy-skeletal, mixed, 5 to 30
percent slopes

The Typic Cryumbrepts are moderately deep, moderately well and well drained soils. Typically, they formed in granitic glacial till with an influence of volcanic ash, over a dense, compact hardpan and localized material from rhyolitic tuff. Less commonly, these soils formed in colluvium and residuum with an influence of till and ash, and are underlain by granodiorite. Soils underlain by bedrock are usually found on shoulders and scoured ridgetops with thin morainal deposits, or on footslopes and adjacent to drainages where erosion has removed these deposits. The formation and parent material of the Dystric Cryochrepts do not differ significantly from the Typic Cryumbrepts other than the former have a greater influence of volcanic ash in the solum. Dystric Cryochrepts are found on ridges, concave areas, and more northerly slopes of moraines where accumulation of ash has been favored by position, and erosion off of rock outcrops and boulders.

Vegetation is predominantly uneven-aged lodgepole pine, occasionally with mountain hemlock and western white pine on more northerly aspects and near drainages and wet areas. Canopy cover varies

from about 35 to 60 percent. The understory is mostly grasses, sedges, and ribes.

Included in this unit are:

- 10% Sandy-skeletal, mixed, Dystric Cryochrepts and Typic Cryorthents, 5 to 30 percent slopes
- 5% Granitic rock outcrop
- 5% Typic Cryofluvents

53 Typic Cryumbrepts, 25 to 55 percent south slopes

This map unit has 4 delineations on steep, bouldery, south-facing slopes of lateral moraines. They are in the Moraine Flat area and east of Lemberg Dome.

- 85% Typic Cryumbrepts, loamy-skeletal, mixed, 25 to 55 percent slopes.

The Typic Cryumbrepts are well drained soils forming in granitic glacial till with an admixture of volcanic ash. These soils are commonly moderately deep to hardpan till, rhyolitic tuff, or granodiorite bedrock. Less commonly, they are deep in unconsolidated morainal till.

Vegetation is lodgepole pine, grass, sedge, and ribes.

Included in this unit are:

- 5% Granitic outcrop
- 5% Lithic Cryumbrepts, loamy-skeletal, mixed, 25 to 45 percent slopes

5% Typic Cryorthents, sandy-skeletal, mixed, 25 to 55 percent slopes

54 Typic Cryumbrepts, 15 to 45 percent north slopes

The map unit is found on complex, benched, north-facing backslopes and often slightly concave footslopes of bouldery moraines on glacially eroded granitic mountainsides. There are 7 delineations, all in the southwestern portion of the survey area near Tenaya Peak, and Medicott, Polly, and Fairview Domes.

85% Typic Cryumbrepts, loamy-skeletal, mixed, 15 to 45 percent slopes

The Typic Cryumbrepts are well drained, deep soils forming in granitic colluvium over glacial till with an influence of volcanic ash in the upper solum.

Vegetation is a mixed coniferous forest of red fir, lodgepole pine, mountain hemlock, and western white pine. The understory contains sparse grass and sedges but good regeneration of coniferous species.

Included in this unit are:

5% Granitic outcrop

5% Talus, rubbleland, and Cryorthents resulting from landslides

5% Dystric Cryochrepts, loamy-skeletal, mixed, 15 to 45 percent slopes

55 Typic Cryumbrepts - Lithic Cryochrepts - Jointed granitic
outcrop complex, 5 to 30 percent slopes

The mapping unit is on extremely bouldery shoulders, footslopes, and valleys of glacially scoured granitic mountains. There are 13 delineations of this map unit.

- 40% Typic Cryumbrepts, loamy-skeletal, mixed, 5 to 30 percent slopes
- 25% Lithic Cryochrepts, loamy, mixed, 5 to 30 percent slopes
- 20% Jointed granitic outcrop

The Typic Cryumbrepts are moderately well and well drained soils that occupy mostly concave depositional areas along drainageways, and on benches and footslopes between glacially scoured outcrops of granitic rocks. They are moderately deep or deep soils forming in colluvium, glacial till, or rhyolitic tuff, with an influence of volcanic ash in the upper solum. The Lithic Cryochrepts are well to somewhat excessively drained shallow soils formed in colluvium and residuum from glacially scoured granitic rocks with a component of volcanic ash. These soils are found in joints and crevices of rock outcrops and on ledges, benches, and sideslopes. The granitic rock is granodiorite and granodiorite porphyry.

Vegetation is uneven-aged lodgepole pine with grasses, sedges, and a few low shrubs such as ribes and chinquapin. Canopy cover is fair on the Typic Cryumbrepts and sparse on the Lithic Cryochrepts.

Included in this map unit are:

- 5% Lithic Cryorthents, sandy or sandy-skeletal, mixed,
5 to 30 percent slopes
- 5% Typic Cryorthents, sandy or sandy-skeletal, mixed,
5 to 30 percent slopes
- 4% Cryofluvents
- 1% Kettles and small ponds

**60 Typic Xerumbrepts - Lithic Xerumbrepts - Jointed granitic
outcrop complex, 30 to 60 percent slopes**

The map unit is on extremely bouldery south-facing sideslopes of glacially scoured granitic mountains. There are 4 delineations in the vicinity of Fairview, Polly, and Lember Domes.

- 45% Typic Xerumbrepts, loamy-skeletal, mixed, frigid, 30
to 60 percent slopes
- 30% Lithic Xerumbrepts, loamy, mixed, frigid, 30 to 60
percent slopes
- 20% Jointed granitic outcrop

The Typic Xerumbrepts are moderately deep, well drained soils forming in colluvium, till, and rhyolitic tuff over granodiorite. They are on slightly concave mid and lower sideslopes. The Lithic Xerumbrepts are shallow, well drained soils over granodiorite. They are associated with rock outcrop.

Vegetation is western juniper, Jeffrey pine, lodgepole pine, and chinquapin on the Typic Xerumbrepts. Manzanita, Phlox, and western juniper is characteristic of the Lithic Xerumbrepts.

Included with this unit are:

5% Lithic Cryochrepts loamy-skeletal, mixed, 30 to 60 percent slopes

70 Metamorphic talus - Lithic Cryochrepts - Jointed metamorphic outcrop complex, 45 to 75 percent slopes

The map unit has 3 delineations on the flanks of Gaylor Peak, and Mounts Dana and Gibb. This unit is on mountain ridges and sideslopes. The exposed brownish metamorphosed volcanic and sedimentary rock is high in quartz and pyroclastic material.

60% Metamorphic talus

15% Lithic Cryochrepts, loamy-skeletal, mixed, 45 to 75 percent slopes

15% Jointed metamorphic outcrop

The talus is composed of channers, flags, and stone-size fragments with less than 5 percent soil material. The Lithic Cryochrepts are shallow, somewhat excessively drained soils forming in colluvium and residuum from metamorphic rock. The outcrop consists of exposed, mainly vertically jointed metavolcanic or metasedimentary rock.

Vegetation is scattered, clumped and prostrate whitebark pine and sagebrush, with grass, sedges, phlox, and mountain heather.

Included with this unit are:

5% Lithic Cryorthents, loamy-skeletal, mixed, 5 to 45 percent slopes

5% Dystric Cryochrepts, loamy skeletal, mixed, 35 to 55 percent slopes

The Lithic Cryorthents are very shallow soils, mostly on exposed ridges and saddles. The Dystric Cryochrepts are deep soils on colluvial fans.

71 Metamorphic outcrop - Lithic Cryochrepts - Typic Cryumbrepts complex, 15 to 75 percent slopes

The map unit is located on mountain ridges, shoulders and sideslopes, along the contact between granitic and metamorphic rocks. There are 4 delineations near Gaylor Peak and above Parker Pass Creek.

60% Metamorphic outcrop

20% Lithic Cryochrepts, loamy, mixed, 25 to 75 percent slopes

15% Typic Cryumbrepts, loamy-skeletal, mixed, 15 to 40 percent slopes

The outcrop is mostly vertically jointed metavolcanic and meta-sedimentary rocks such as tuffs and hornfels. The Lithic Cryochrepts formed in residuum and colluvium from mostly metavolcanic rocks in cracks, fissures, and around rock outcrop. The Typic Cryumbrepts are mostly deep, well drained soils that formed in mixed colluvium from metamorphic and granitic rocks. They occur on concave benches and around bases of rock outcrops. Both soils also contain a component of volcanic ash.

Vegetation is scattered, stunted whitebark pine growing in shallow pockets of soil associated with rock outcrop. Grass and sedge outcompetes trees and shrubs on the deep soil on benches.

Included in this unit are:

- 4% Metamorphic talus
- 1% Cryofluvents and seeps

72 Metamorphic outcrop - Metamorphic talus - Typic Cryumbrepts complex, 35 to 130 percent slopes

There are 5 delineations of this map unit along the Sierra Crest. The unit is located on mountain ridges, shoulders, and sideslopes, mainly above tree-line.

- 35% Metamorphic outcrop, 45 to 130 percent slopes
- 30% Metamorphic talus, 45 to 75 percent slopes
- 25% Typic Cryumbrepts, loamy-skeletal, mixed, 35 to 50 percent slopes

The metamorphic rocks include volcanic tuffs and flows, shale, local graywackes, and calc-silicate hornfels. The talus consists of angular channers, flags, and boulders found below rock outcrop. The Typic Cryumbrepts formed in colluvium. They are well drained, deep and moderately deep soils.

Vegetation is mainly low growing shrubs like mountain heather, with phlox, buckwheat, and sedges. Scattered, stunted clumps of whitebark pine are also present.

Included in this map unit are:

- 10% Lithic Cryorthents, loamy-skeletal, mixed located around rock outcrops

80 Lithic Cryochrepts - Jointed granitic outcrop - Typic
Cryumbrepts complex, 5 to 30 percent slopes

There are 3 delineations of this map unit that occurs on glacially scoured valley floors and plateaus.

- 40% Lithic Cryochrepts, loamy, mixed, 5 to 15 percent slopes
- 30% Jointed granitic outcrop
- 20% Typic Cryumbrepts, loamy-skeletal, mixed, 10 to 30 percent slopes

The Lithic Cryochrepts are well drained soils forming in a thin mantle of volcanic ash and glacial till over granodiorite. They are on ledges, benches, fissures, and joints on and around rock outcrop. The rock outcrop is sparsely jointed, glacially modified and mostly smooth with a gently rolling surface of exposed Cathedral Peak or Half Dome granodiorite. The Typic Cryumbrepts are mainly well drained, moderately deep soils forming in mixed colluvium, slopewash, glacial till, and volcanic ash, underlain by dense, compacted glacial till or volcanic tuff. They occur mainly in concave areas associated with larger joints. Areas along drainages and lower sideslopes are deep, moderately well drained, and have fewer coarse fragments.

Vegetation is uneven-aged lodgepole pine, grass, sedge, manzanita, sagebrush, and ribes. Canopy cover is about 10 percent on shallow soils, and about 25 to 50 percent on deeper soils.

Included in this map unit are:

- 5% Typic Cryorthents, sandy-skeletal, mixed, 5 to 30 percent slopes

- 5% Typic Cryofluvents, loamy-skeletal, mixed, 0 to 15 percent slopes. Poorly and somewhat poorly drained alluvial soils

81 Lithic Cryumbrepts - Dystric Cryochrepts - Jointed granitic outcrop complex, 30 to 55 percent slopes

The map unit is on glacially scoured shoulders and backslopes of granitic mountains. There are 9 delineations that occur in the western portion of the survey area.

- 35% Lithic Cryumbrepts, loamy, mixed, 30 to 55 percent slopes
25% Dystric Cryochrepts, loamy-skeletal, mixed, 30 to 55 percent slopes
25% Jointed granitic outcrop

The Lithic Cryumbrepts are well to somewhat excessively drained soils formed in colluvium and residuum from granitic rocks with an influence of volcanic ash. They occupy ledges, benches, rock fissures, and steep slopes in complex association with rock outcrop. The Dystric Cryochrepts are moderately deep and deep, moderately well to well drained soils. They formed in colluvium and residuum from granitic rocks, granitic glacial till, weathered tuff, and volcanic ash. They occupy concave positions in small drainageways, and are on benches, sideslopes, and colluvial fans. The rock outcrop is Half Dome and Cathedral Peak granodiorite.

Vegetation is uneven-aged lodgepole pine. The canopy varies from 5 to 15 percent on Lithic Soils in association with rock outcrop, to 25 to 50 percent on deeper soils in concave positions. The understory includes fescue and sedges, with ribes, manzanita, and sagebrush.

Included with this unit are:

- 10% Lithic Cryumbrepts, loamy-skeletal, mixed, 30 to 55 percent slopes
- 4% Lithic Cryorthents, sandy-skeletal, mixed, 30 to 55 percent slopes
- 1% Cryofluvents

82 Lithic Cryochrepts - Jointed granitic outcrop complex, 5 to 30 percent slopes

There are 4 delineations of this map unit near the northern survey boundary below Ragged Peak and White Mountain. The unit is on glacially scoured cirque basins.

- 60% Lithic Cryochrepts, loamy, mixed, 5 to 30 percent slopes
- 20% Jointed granitic outcrop

The Lithic Cryochrepts formed in thin layers of residuum and glacial till overlying scoured, sparsely jointed granodiorite. The surface is usually extremely bouldery.

Vegetation is small stands of lodgepole and whitebark pine with sedge, phlox, and buckwheat.

Included in this unit are:

- 10% Sandy-skeletal soils, Lithic and Typic Cryorthents, mixed, 5 to 30 percent slopes
- 10% Typic Cryumbrepts, loamy-skeletal, mixed, 5 to 30 percent slopes

90 Dystric Cryochrepts - Typic Cryumbrepts - metamorphic talus complex, 45 to 75 percent slopes

This map unit has 2 delineations on extremely stony, unstable, middle and lower sideslopes below Mount Dana and Mount Gibbs.

40% Dystric Cryochrepts, loamy-skeletal, mixed, 45 to 65 percent slopes

25% Typic Cryumbrepts, loamy-skeletal, mixed, 45 to 65 percent slopes

20% Metamorphic talus, 50 to 75 percent slopes

The Dystric Cryochrepts are deep, well drained soils found on lower convex sideslopes. The Typic Cryumbrepts are on upper and middle sideslopes. Both soils are deep and well drained, forming in colluvium and volcanic ash. The talus is composed of flags, channers, stones, and boulders from metamorphic rocks such as volcanic tuffs, quartzite, and calc-silicate hornfels.

Vegetation is mainly lodgepole pine on lower sideslopes and whitebark pine on upper sideslopes, with sedges and grasses.

Included in this unit are:

5% Metamorphic outcrop

10% Pachic Cryoborolls, loamy-skeletal, mixed, 45 to 60 percent slopes

The Pachic Cryoborolls have thick dark surfaces, are somewhat poorly drained, and occur on lower concave sideslopes in association with seeps.

91 Dystric Cryochrepts, 15 to 60 percent slopes

This map unit has 2 delineations located on backslopes and foot-slopes of the glacially carved Parker Pass Creek valley. The complex dissected and benched morainal slopes are mostly 25 to 45 percent, but slope limits widened to accommodate benches and steep dissections. Surface is very stony to extremely bouldery.

85% Dystric Cryochrepts, loamy-skeletal, mixed, 15 to 60 percent slopes

These are well drained, deep and moderately deep soils forming in colluvium and glacial till, with the influence of volcanic ash. Rock fragments are from mixed granitic and metamorphic sources. On lower sideslopes and benches, a dense, brittle till pan may occur between 20 to 40 inches.

Vegetation is predominantly lodgepole pine with minor amounts of mountain hemlock and whitebark pine on upper slopes. Understory is mostly grasses, sedges, and ribes.

Included with this unit are:

5% Metamorphic rock outcrop

10% Typic Cryumbrepts, loamy-skeletal, mixed, 20 to 45 percent slopes.

100 Dystric Cryochrepts, 15 to 45 percent slopes

There are 6 delineations of this map unit. They occur on more or less northerly slopes on extremely bouldery dissected lateral moraines and sideslopes of granitic mountains.

80% Dystric Cryochrepts, loamy-skeletal, mixed, 15 to 45 percent slopes

These soils are well drained, forming in colluvium and residuum from granitic rocks, glacial till, and influenced by volcanic ash in the upper solum. They may be deep in glacial till, but commonly are moderately deep over granodiorite or dense till pan.

Vegetation is primarily lodgepole pine with mountain hemlock and minor western white pine. Understory is grass, sedges, and ribes. Canopy cover varies from 35 to 65 percent.

Included in this map unit are:

10% Typic Cryumbrepts, loamy-skeletal, mixed, 15 to 45 percent slopes

5% Sandy-skeletal, Typic Cryorthents and Dystric Cryochrepts, 15 to 45 percent slopes

3% Cryofluvents, wet meadows, and Pachic Cryoborolls along drainages and seeps

2% Granitic rock outcrop or rubbleland from landslides

101 Dystric Cryochrepts - Jointed granitic outcrop - Lithic Cryochrepts complex, 40 to 75 percent slopes

This map unit has 11 delineations that occur on the upper timbered sideslopes of granitic mountains.

40% Dystric Cryochrepts, loamy-skeletal, mixed, 40 to 75 percent slopes

25% Jointed granitic outcrop

15% Lithic Cryochrepts, loamy, mixed, 40 to 75 percent slopes

The Dystric Cryochrepts are deep, well drained soils forming in colluvium, glacial till, and volcanic ash, which are underlain by granodiorite. They occur on slightly concave sideslopes with very bouldery surfaces. The Lithic Cryochrepts are formed in the same material and occur between rock joints and crevices.

Vegetation is whitebark pine and lodgepole pine, with sedges, ribes, mountain heather, and mountain sagebrush.

Included in this map unit are:

- 10% Typic Cryumbrepts and Lithic Cryumbrepts, loamy-skeletal, mixed, 40 to 75 percent slopes
- 7% Granitic talus
- 3% Cryofluvents, 15 to 35 percent slopes

102 Dystric Cryochrepts - Aeric Cryaquepts complex, 0 to 15 percent slopes

This map unit is on hummocky, alpine meadows at elevations above 9400 feet. The unit is characterized by morainal ridges and depressions, often dotted with large boulders, and a number of small lakes or kettles are prominent. The unit has 9 delineations.

- 65% Dystric Cryochrepts, loamy-skeletal and coarse-loamy, mixed, 5 to 15 percent slopes
- 20% Aeric Cryaquepts, fine-loamy, mixed, 0 to 10 percent slopes

The Dystric Cryochrepts are moderately deep to a brittle till pan. They are moderately well drained soils forming on convex slopes

and ridges of morainal deposits. Commonly, these soils contain many rock fragments (>35%) in the profile and the surface is very stony to extremely bouldery. Less commonly, the soil profile averages 15 to 35 percent rock fragments, and it may be somewhat poorly drained in areas adjacent to depressions. The Aeric Cryaquepts are poorly and very poorly drained soils in depressions and along drainageways. They are also underlain by a hardpan and are moderately deep. The morainal deposits are primarily granitic, but metamorphic rocks influence the till along Parker Pass Creek.

Vegetation is mainly water tolerant sedges and grasses, but includes encroaching whitebark and lodgepole pine, and willow on wetter sites.

Included in this unit are:

- 5% Sandy-skeletal, mixed Typic Cryorthents and Dystric Cryochrepts
- 5% Sandy-skeletal, mixed Typic Cryofluvents
- 5% Small lakes and ponds

The sandy-skeletal Typic Cryorthents and Dystric Cryochrepts are found on coarse poorly sorted outwash and morainal deposits. The Typic Cryofluvents are along drainageways and creeks.

110 Typic Cryofluvents, 0 to 5 percent slopes

There are 5 delineations of this map unit. These are the wet alluvial areas of Tuolomne and Dana Meadows. They are on glacially eroded valley floors.

- 70% Typic Cryofluvents, coarse-loamy, mixed, 0 to 5 percent slopes
- 20% Typic Cryofluvents, sandy-skeletal, mixed, 0 to 3 percent slopes

These are the very deep, somewhat poorly to poorly drained soils forming in Holocene valley fill material in glaciated sub-alpine meadow areas. The material ranges from loamy to very coarse and depth to sand and gravel ranges from 12 to greater than 60 inches.

Vegetation is grasses, sedges, and hydrophilic plants. Lodgepole pine is often encroaching on the better drained meadow edges. Included in this unit are:

- 5% Humic and Aeric Cryaquepts, fine-loamy, mixed, 0 to 2 percent slopes
- 3% Granitic outcrop (especially western Tuolumne Meadows)
- 2% Streams and channels

W Lakes and Other Water Bodies

This miscellaneous unit has 14 delineations. These are kettles or tarns of 5 acres or more that are all associated with glacial scouring and depositions.

Examples are Tenaya, Dog, Polly, Cathedral, and Helen Lakes.

SOIL SURVEY OF
DOUGHERTY PEAK STUDY AREA
KINGS CANYON NATIONAL PARK

DESCRIPTION OF THE AREA

LOCATION

The Dougherty Peak study area encompasses approximately 25,000 acres within the west-central portion of the Kings Canyon National Park (Marion Peak 15' quadrangle. Located within the Sierra Nevada of California, the study area lies between the coordinates of latitudes $36^{\circ} 48'$ and $37^{\circ} 00'$ north and longitudes $118^{\circ} 31'$ and $118^{\circ} 38'$ west.

The Kings River forms the northern boundary; Murray Ridge, Cirque Crest, and Goat Crest the east boundary; and Dead Pine Ridge the west boundary. The southern boundary begins at Kennedy Pass, continues east along Comb Spur before crossing Granite Basin and continuing north to Goat Crest. The Dougherty Peak study area is located in southeastern Fresno County.

TERRAIN

The complex terrain is characterized by deeply incised canyons, glacial basins and valleys, mountain summits, cirques, and tarns. The terrain is very rugged with elevations ranging from 5,900 to 12,600 feet. The topography is predominantly complex with very steep to extremely steep slopes. The terrain reflects the land-forming influence of extensive glaciation so characteristic of the High Sierra. Cirque lakes, deeply incised basins and expanses of exposed granitic peaks and walls are common features.

GENERAL GEOLOGY

Typical of the western slope of the Southern Sierra Nevada, Cretaceous age granite, granodiorite, and similar acid-igneous rocks comprise the vast majority of the Dougherty Peak study area. Remnant mafic plutonic and metavolcanic rocks (Mesozoic) occur as small islands south and east of State Lakes, along the southeast corner of Dead Pine Ridge and around Windy Peak.

The area has been heavily glaciated. Only a few small alpine peaks and summits occurring at elevations of 11,000 feet or higher remain unglaciated. The glaciers left relatively little debris behind them. This is supported by the large amount of shallow soils in this area. Many traces of past glaciation remain including the presence of moraines, erratic boulders, chain lakes, cirques, tarns, and glacial polish on rocks.

VEGETATION

The natural vegetation reflects the soil and climatic patterns of the area. There are six communities in this area:

- o Mountain Chaparral
- o Jeffrey Pine Forest
- o Red Fir Forest
- o Lodgepole Pine Forest
- o Subalpine Forest
- o Subalpine and Alpine Meadow

The Mountain Chaparral and Jeffrey Pine Forest communities occupy the lowest and warmest areas, elevation from 5,900 feet to 8,000 feet on the warmer aspects. Wildfires are common. Brush thickets composed of plants such as snow brush, bitter cherry, manzanita, sagebrush, chinquapin and canyon oak comprise the mountain chaparral community. They occupy dry and rocky slopes often in

association with talus. The soils are predominantly shallow and skeletal, commonly having well developed subsoils. Jeffrey pine along with black oak, incense cedar, sugar pine, white fir and western juniper make up the primary plants in the Jeffrey Pine Forest. This community often has a shrub understory. The soils tend to be moderately deep and deep, and typically skeletal and coarse textured.

Red Fir Forest community occurs on cool, well drained soils at elevations from 7,000 to 9,000 feet. They occur in even-aged stands with few associates. The sites they occupy often receive high amounts of snowfall.

The largest community in the survey area is the Lodgepole Forest. It ranges from 8,000 to 11,000 feet and occurs on glacially scoured ridges, valleys and basins and lower mountain sideslopes. The soils are cold and normally poorly developed but range greatly in depth. Typically the understory is sparse and consequently, litter accumulation is low.

The next higher community, the Subalpine Forest, is found on rocky mountain ridges, crests and sideslopes at elevations from 9,500 to 12,000 feet. The trees appear stunted and sparsely scattered. They include lodgepole pine, western white pine, and whitebark pine with very little understory or litter. Soils are shallow and very shallow.

The highest community, the Alpine Community, occurs on the upper glacial basins and upper mountain ridges and sideslopes above timberline. Plants are low growing and consist of alpine herbs such as pussypaws, dwarf Lewisia, buckwheat, and shrubs such as currant and willow. Soils are very shallow and shallow and very cold.

The last community is the Subalpine and Alpine Meadows. They are dominated by various species of sedges, meadow grasses, and willows. Soils are mostly deep and are very poorly and poorly drained.

TABLE 1-KC

SOIL TAXONOMIC UNITS
(Alphabetical order)

Dougherty Peak Study Area

Kings Canyon National Park

Entic Xerumbrepts, loamy-skeletal, mixed, mesic
Humic Cryaquepts, sandy-skeletal, mixed
Lithic Cryumbrepts, loamy-skeletal, mixed
Lithic Cryumbrepts, sandy-skeletal, mixed
Lithic Mollic Haploxeralfs, loamy-skeletal, mixed, frigid
Lithic Xerorthents, sandy-skeletal, mixed, frigid
Lithic Xerumbrepts, loamy-skeletal, mixed, frigid
Lithic Xerumbrepts, loamy-skeletal, mixed, mesic
Typic Cryofluvents, sandy, mixed
Typic Cryorthents, sandy-skeletal, mixed
Typic Cryorthents, sandy-skeletal, mixed, shallow
Typic Cryumbrepts, loamy-skeletal, mixed
Typic Xerumbrepts, loamy-skeletal, mixed, frigid

TABLE 2-KC
CLASSIFICATION TABLE OF TAXONOMIC UNITS
Dougherty Peak Study Area
Kings Canyon National Park

ALFISOLS

Haploxeralfs

Lithic Mollic Haploxeralfs, loamy-skeletal, mixed, frigid

ENTISOLS

Cryofluvents

Typic Cryofluvents, sandy, mixed

Cryorthents

Typic Cryorthents, sandy-skeletal, mixed
Typic Cryorthents, sandy-skeletal, mixed, shallow

Xerorthents

Lithic Xerorthents, loamy-skeletal, mixed, frigid

INCEPTISOLS

Cryaquepts

Humic Cryaquepts, sandy-skeletal, mixed

Cryumbrepts

Typic Cryumbrepts, loamy-skeletal, mixed
Lithic Cryumbrepts, loamy-skeletal, mixed
Lithic Cryumbrepts, sandy-skeletal, mixed

Xerumbrepts

Typic Xerumbrepts, loamy-skeletal, mixed, frigid
Entic Xerumbrepts, loamy-skeletal, mixed, mesic
Lithic Xerumbrepts, loamy-skeletal, mixed, mesic
Lithic Xerumbrepts, loamy-skeletal, mixed, frigid

TAXONOMIC UNITS IN THE DOUGHERTY PEAK STUDY AREA

DESCRIPTION OF TAXONOMIC UNITS

Entic Xerumbrepts, loamy-skeletal, mixed, mesic

This soil family consists of moderately deep and deep, somewhat excessively drained soils that formed in colluvium from granitic rock sources. They occur on canyon sideslopes. Slopes range from 45 to 75 percent slopes.

These soils are poorly developed and have moderately coarse textures. Typically they have a moderately thick dark colored surface layer over a lighter colored substratum.

Following is a profile description of a representative pedon (88-2K-27) found in the map unit 29 *Jointed dacitic outcrop - Lithic Xerumbrepts - Typic Xerumbrepts complex, 45 to 130 percent slopes*. It is located near the Simpson Meadow about 1 mile southwest of Windy Peak on the Marion Peak 15' quadrangle. Elevation is approximately 6700 feet.

Oi--0.5 to 0 inches; slightly decomposed conifer needles and shrubs leaves and twigs.

A1--0 to 5 inches; brown (10YR 4/3) very stony coarse sandy loam, very dark grayish brown (10YR 3/2) moist; moderate very fine and fine granular structure; soft very friable, nonsticky and nonplastic; many very fine and fine roots; many fine and medium interstitial pores; 30 percent pebbles, 10 percent cobbles, and 10 percent stones; abrupt wavy boundary.

AC--5 to 19 inches; yellowish brown (10YR 5/4) very cobbly coarse sandy loam, dark brown (10YR 3/3) moist; weak very fine and fine subangular blocky structure; common very fine, fine and medium roots; common very fine and fine interstitial pores; 20 percent pebbles, 20 percent cobbles, and 10 percent stones; clear wavy boundary.

C--19 to 42 inches; yellowish brown (10YR 5/4) very cobbly coarse sandy loam, brown (10YR 4/3) moist; massive; few fine and medium roots; common very fine and medium interstitial pores; 20 percent pebbles, 30 percent cobbles, and 10 percent stones.

Remarks: About a third of the soils surfaces have litter on them. The soil temperature taken at 20 inches on 7/13/88 at 1:00 p.m. was 68°F.

Humic Cryaquepts, sandy-skeletal, mixed

This soil family consists of deep, very poorly and poorly drained soils that formed in alluvium and some morainal material weathered from granitic rock sources. They occur on drainageways and around seeps. Slopes range from 5 to 15 percent.

Typically they have very dark colored surface layers over lighter colored stratified substratums that are frequently mottled.

Following is a profile description of a representative pedon (88-2K-04) found on map unit 90 *Humic Cryaquepts-Typic Cryofluvents complex, 0 to 15 percent slopes*. It is located north of Glacier Lakes about 7,054 feet S20°E of bench mark (BM) 9652 on the Marion Peak Quadrangle, USGS (photo 7-222). The elevation is 32,710 m (9,970 feet), 15 percent slope on a southeast aspect.

Oa--0 to 9 inches; dark gray (10YR 4/1) "silty" muck held together by many very fine and fine roots, very dark brown (10YR 2/2) moist; structureless; friable, slightly sticky and slightly plastic; many very fine interstitial pores; abrupt wavy boundary.

A--9 to 12 inches; dark gray (10YR 4/1) silt loam, black (10YR 2/1) moist; massive; many very fine roots; many very fine interstitial pores; abrupt wavy boundary.

2Cg--12 to 23 inches; gray (5Y 5/1) gravelly coarse sandy loam, dark gray (5Y 4/1) moist; massive; friable, nonsticky and nonplastic; common very fine interstitial pores; gradual wavy boundary.

3Cg--23 to 60 inches; gray (5Y 5/1) extremely cobbly coarse sand, dark gray (5Y 4/1) moist, few medium distinct yellowish brown (10YR 5/6) iron mottles; single grained; loose, loose, nonsticky and nonplastic; 15 percent pebbles, 40 percent cobbles, and 10 percent stones.

Remarks: The water table was at 25 inches on 7/5/88.

Lithic Cryumbrepts, loamy-skeletal, mixed

This soil map unit consists of very shallow and shallow, well and somewhat excessively drained soils that formed in residuum and some colluvium weathered from granitic rock sources.

Typically they have a dark surface layer over a brighter (higher chroma) subsoil resting over granitic rock.

Following is a profile description of a representative pedon (88-2K-17) found in the map unit *22 Jointed granitic outcrop* -

Lithic Cryumbrepts complex, 15 to 45 percent slopes. It is located north of Granite Lake about 0.5 mile south of Granite Pass on the Marion Peak 15' quadrangle. Elevation is approximately 10200 feet.

Oi--0.5 to 0 inches; slightly decomposed conifer needles, twigs and cones.

A1--0 to 4 inches; very dark grayish brown (10YR 3/2) extremely bouldery coarse sandy loam, very dark brown (10YR 2/2) moist; moderate very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; many fine and medium interstitial pores; 20 percent pebbles, 15 percent cobbles, 15 percent stones, and 20 percent boulders; abrupt wavy boundary.

A2--4 to 11 inches; dark yellowish brown (10YR 3/4) extremely stony coarse sandy loam, dark yellowish brown (10YR 3/4) moist; moderate very fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; many fine and medium interstitial pores; 15 percent pebbles, 15 percent cobbles, 20 percent stones, and 15 percent boulders; abrupt wavy boundary.

A3--11 to 18 inches; dark yellowish brown (10YR 4/4) extremely stony coarse sandy loam, dark yellowish brown (10YR 3/4) moist; weak very fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very and fine roots; common fine and medium pores; 10 percent pebbles, 30 percent cobbles, 30 percent stones, and 20 percent boulders; abrupt wavy boundary.

2R--18 inches; fractured granitic rock.

Remarks: The soil temperature taken at 18 inches on 7/9/88 at 10:00 a.m. was 60°F.

Lithic Cryumbrepts, sandy-skeletal, mixed

This soil family consists of very shallow and shallow, excessively drained soils that formed in residuum and colluvium from granitic rock sources. They occur on unglaciated canyon sideslopes. Slopes range from 45 to 75 percent slopes.

Typically they have a dark surface layer resting on top of hard granitic rock.

Following is a profile description of a representative pedon (88-2K-20) found in the map unit 110 *Lithic Cryumbrepts - Lithic Xerorthents - Jointed granitic outcrop complex, 45 to 75 percent slopes*. It is located near Windy Peak about 1.5 miles southeast of Simpson Meadow on the Marion Peak 15' quadrangle. Elevation is approximately 8400 feet.

Oi--0.5 to 0 inches; slightly decomposed conifer needles, twigs and cones.

A1--0 to 3 inches; brown (10YR 5/3) extremely gravelly loamy coarse sand, very dark grayish brown (10YR 3/2) moist; moderate very fine granular structure; common very fine roots; common very fine interstitial pores; 65 percent pebbles, 5 percent cobbles; clear wavy boundary.

A2--3 to 7 inches; brown (10YR 5/3) extremely gravelly loamy coarse sand, dark brown (10YR 3/3) moderate fine and medium subangular blocky structure; many very fine

and common fine roots; common very fine interstitial pores; 60 percent pebbles, 5 percent cobbles; clear wavy boundary.

C--7 to 13 inches; pale brown (10YR 6/3) very gravelly loamy sand, brown (10YR 5/3) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine and medium roots; common very fine interstitial pores; 50 percent pebbles, 5 percent cobbles; abrupt wavy boundary.

2R--13 inches; hard, fractured granitic rock.

Remarks: The soil temperature taken at 13 inches on 7/12/88 was 59°F.

Lithic Mollic Haploxeralfs, loamy-skeletal, mixed, frigid

This soil family consists of very shallow and shallow, well drained soils that formed in residuum and colluvium from granitic rock sources. They occur on canyon sideslopes around jointed granitic outcrop. Slopes range from 45 to 75 percent.

Typically these soils have dark colored layers and a well developed subsoil that rests on granite.

Following is a profile description of a representative pedon (88-2K-24) found in the map unit 60 *Lithic Xerumbrepts - Lithic Mollic Haploxeralfs - Typic Xerumbrepts complex, 45 to 75 percent slopes*. It is located 1.5 miles northeast of Windy Peak on the north-northwest facing slopes of Windy Ridge on the Marion Peak 15' quadrangle. Elevation is approximately 8,000 feet.

A1--0 to 2 inches; grayish brown (10YR 5/2) extremely gravelly coarse sandy loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common very fine roots; common very fine interstitial pores; 45 percent pebbles, 20 percent cobbles, and 5 percent stones; clear wavy boundary.

A2--2 to 6 inches; grayish brown (10YR 5/2) very cobbly coarse sandy loam, very dark brown (10YR 2/2) moist, weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine roots; common very fine interstitial and few fine tubular pores; 20 percent pebbles, 20 percent cobbles, and 10 percent stones; abrupt wavy boundary.

Bt--6 to 10 inches; brown (10YR 5/3) cobbly loam, brown (10YR 3/3) moist; moderate medium and coarse angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine and fine tubular pores; common thin clay films on ped faces and few moderately thick clay films lining pores; 10 percent pebbles, 15 percent cobbles, and 5 percent stones; abrupt smooth boundary.

2R--10 inches; hard granitic rock.

Remarks: The Bt horizon has 18 to 27 percent clay.

Lithic Xerorthents, sandy-skeletal, mixed, frigid

This soil family consists of very shallow and shallow, excessively drained soils that formed in colluvium and residuum from granitic

rock sources. They occur on unglaciated canyon sideslopes. Slopes range from 45 to 75 percent slopes.

These soils are little developed. They have light colored coarse textured layers over granitic rock.

Following is a profile description of a representative pedon (88-2K-23) found in the map unit 110 *Lithic Cryumbrepts - Lithic Xerorthents - Jointed granitic outcrop complex, 45 to 75 percent slopes*. It is located east of Dougherty Creek about 1.5 miles southeast of Simpson Meadow on the Marion Peak 15' quadrangle. Elevation is approximately 7800 feet.

A1--0 to 2 inches; light brownish gray (10YR 6/2) extremely gravelly coarse sandy loam, brown (10YR 5/3) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; common very fine roots; common very fine interstitial pores; 65 percent pebbles; abrupt wavy boundary.

C1--2 to 12 inches; very pale brown (10YR 7/2) extremely gravelly loamy coarse sand, pale brown (10YR 6/3) moist; weak fine subangular blocky structure; common very fine roots; many very fine interstitial pores; 60 percent pebbles; clear wavy boundary.

2Cr--12 to 16 inches; granitic grus.

2R--16 inches; hard granitic rock.

Remarks: Depth to rock ranges from 4 to 16 inches. A thin layer of grus is commonly present. Coarse fragments are mainly small pea size pebbles. The soil temperature taken at 12 inches on 7/14/88 was 67°F.

Lithic Xerumbrepts, loamy-skeletal, mixed, frigid

This soil family consists of shallow, somewhat excessively drained soils that formed in colluvium and residuum weathered from granitic rock sources. They occur on rocky crests and ridges of canyons. Slopes range from 15 to 75 percent.

These soils have moderately coarse textures. They have a dark surface layer overlying a lighter colored and brighter chroma subsoil which rests on granitic rock.

Following is a profile description of a representative pedon (88-2K-26) found in the map unit 60 *Lithic Xerumbrepts - Lithic Mollic Haploxeralfs - Typic Xerumbrepts complex*, 45 to 75 percent slopes. It is located northeast of Windy Peak on the north-northwest facing slopes of Windy Ridge on the Marion Peak 15' quadrangle. Elevation is approximately 8600 feet.

Oi--2 to 0 inches; slightly decomposed manzanita and canyon live oak leaves and conifer needles.

A1--0 to 3 inches; dark grayish brown (10YR 4/2) very cobbly coarse sandy loam, very dark brown (10YR 2/2) moist; weak very fine granular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and few medium and coarse roots; common very fine interstitial pores; 15 percent pebbles, 20 percent cobbles, and 10 percent stones; clear wavy boundary.

A2--3 to 7 inches; grayish brown (10YR 5/2) very cobbly sandy loam, very dark grayish brown (10YR 3/2) moist; weak moderate subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and few medium and coarse roots;

common very fine interstitial and tubular pores; 25 percent pebbles, 20 percent cobbles, and 15 percent stones; clear wavy boundary.

Bw--7 to 17 inches; pale brown (10YR 6/3) very cobbly coarse sandy loam, brown (10YR 4/3) moist; moderate fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine tubular pores; 25 percent pebbles, 20 percent cobbles, and 15 percent stones; abrupt wavy boundary.

2R--17 inches; fractured granitic rock.

Remarks: Depth to bedrock ranges from 10 to 20 inches. About a third of these soils have a litter cover.

Lithic Xerumbrepts, loamy-skeletal, mixed, mesic

This soil family consists of very shallow and shallow to granitic rock, somewhat excessively drained soils that formed in residuum and some colluvium weathered from granitic rock sources. They occur on rocky crests and ridges of canyons and glacial basin sideslopes. Slopes range from 45 to 75 percent.

Typically these soils have a dark colored soil surface layer over a brighter chroma subsoil, in turn resting on hard granitic rock.

Following is a profile description of a representative pedon (88-2K-28) found in the map unit 29 *Jointed dacitic outcrop - Lithic Xerumbrepts - Typic Xerumbrepts complex, 45 to 130 percent slopes*. It is located south of the Simpson Meadow about 1 mile southwest of Windy Peak on the Marion Peak 15' quadrangle. Elevation is approximately 6500 feet.

Oi--0.5 to 0 inches; slightly decomposed conifer needles and oak leaves, twigs and grass.

A1--0 to 4 inches; brown (10YR 5/3) extremely gravelly coarse sandy loam, very dark brown (10YR 2/2) moist; moderate fine and fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; many very fine and medium interstitial pores; 55 percent pebbles, 15 percent cobbles, and 10 percent stones; abrupt wavy boundary.

A2--4 to 10 inches; brown (10YR 5/3) extremely cobbly sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky parting to moderate very fine and fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; common very fine, fine and medium interstitial pores; 45 percent pebbles, 15 percent cobbles, and 10 percent stones; abrupt wavy boundary.

Bw--10 to 15 inches; yellowish brown (10YR 5/4) extremely cobbly coarse sandy loam, dark yellowish brown (10YR 3/4) moist; moderate fine and medium subangular blocky structure; soft, friable, nonsticky and nonplastic; common very fine and fine and few medium roots; common very fine, fine and coarse interstitial pores; abrupt wavy boundary.

2R--15 inches; hard, fracture slightly metamorphosed granitic rock.

Remarks: The soil temperature taken at 15 inches on 7/13/88 at 3:00 p.m. was 62°F.

Typic Cryofluvents, sandy, mixed

This soil family consists of deep, moderately well drained soils that formed in alluvium, colluvium and some morainal material weathered from granitic rock sources. They occur on stream outwash deposits in glacial basins. Slopes range from nearly level to 10 percent.

Typically they have stratified light and slightly dark alluvial layers of coarse textures.

Following is a profile description of a representative pedon (88-2K-18) found in the map unit *90 Humic Cryaquepts - Typic Cryofluvents complex, 0 to 15 percent slopes*. It is located southeast of the Lake of the Fallen Moon about one mile northwest of Glacial Lakes, on the Marion Peak 15' quadrangle. Elevation is approximately 9500 feet.

Oi--1 to 0 inches; slightly decomposed conifer needle, twigs and cones.

A1--0 to 4 inches; brown (10YR 5/3) gravelly coarse sandy loam, dark brown (10YR 3/3) moist; moderate very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; common very fine and fine tubular pores; 15 percent pebbles; abrupt wavy boundary.

A2--4 to 8 inches; pale brown (10YR 6/3) gravelly coarse sand, dark brown (10YR 3/3) moist; weak very fine and fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine and few medium roots; common very fine and fine tubular pores; 20 percent pebbles; abrupt boundary.

2C--8 to 15 inches; light yellowish brown (10YR 6/4) very gravelly loamy coarse sand, brown (10YR 3/3) moist; single grained; loose, loose, nonsticky and nonplastic; few fine and medium roots; common very fine and fine interstitial pores; 40 percent pebbles; abrupt wavy boundary.

3Abg--15 to 31 inches; yellowish brown (10YR 5/4) gravelly loamy sand, brown (10YR 4/3) moist; moderate fine, medium and coarse subangular blocky structure; soft, very friable, nonsticky and nonplastic; many medium distinct dark yellowish brown (10YR 4/6) iron mottles; common fine and medium roots; common very fine and fine tubular pores; 15 percent pebbles; abrupt wavy boundary.

4C--31 to 40 inches; light yellowish brown (10YR 6/4) very gravelly coarse sand, dark yellowish brown (10YR 4/4) moist; single grained; loose, loose, nonsticky and nonplastic; few very fine interstitial pores; 35 percent pebbles; abrupt wavy boundary.

5C--40 to 62 inches; stratified silt loam to very gravelly coarse sand; massive to single grained; friable to loose.

Remarks: The soil has a very thin ash layer at 3 inches. The soil temperature taken at 20 inches on 9/11/88 was 46°F.

Typic Cryorthents, sandy-skeletal, mixed

This soil family consists of moderately deep to granitic rock, excessively drained soils that formed in colluvium and morainal material weathered from granitic rock sources. They occur on

scoured glacial basins and glaciated and unglaciated mountain sideslopes. Slopes range from 15 to 45 percent.

Typically it has a thin slightly darkened surface layer over a light colored substratum.

Following is a profile description of a representative pedon (88-2K-10) found in the map unit *40 Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes*. It is located on the Dead Pine Ridge about one mile northeast of West Kennedy Lake, on the Marion Peak 15' quadrangle. Elevation is approximately 9800 feet.

Oi--1 to 0 inches; slightly decomposed conifer needles, twigs and cones.

A1--0 to 4 inches; grayish brown (10YR 5/2) very gravelly loamy sand, dark brown (10YR 3/3) moist; weak very fine subangular and granular structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots, common very fine and fine interstitial pores; 40 percent pebbles and 5 percent cobbles; abrupt smooth boundary.

A2--4 to 9 Inches; grayish brown (10YR 5/2) gravelly loamy sand, brown (10YR 4/3) moist; weak fine subangular blocky structure; soft very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine interstitial pores; 20 percent pebbles and 5 percent cobbles; abrupt smooth boundary.

C--9 to 40 inches; light olive brown (2.5Y 5/4) very gravelly coarse sand, olive brown (10YR 4/4) moist;

single grained; loose, loose, nonsticky and non-plastic; few fine and medium roots; few very fine interstitial pores; 40 percent pebbles and 10 percent cobbles.

Typic Cryorthents, sandy-skeletal, mixed, shallow

This soil family consists of very shallow and shallow, excessively drained soils that formed in residuum and some colluvium from weathered granitic rock sources. They occur on unglaciated mountain sideslopes and ridges and on glacial basin sideslopes. Slopes range from 15 to 45 percent.

Typically they are light colored soil horizons over soft granitic rock or grus. Textures are coarse.

Following is a profile description of a representative pedon (88-2K-07) found in the map unit *10 Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes*. It is located north of the Glacial Lakes about 0.5 mile west of Glacier Valley on the Marion Peak 15' quadrangle. Elevation is approximately 10400 feet. The slope faces southwest.

(The soil surface is covered by 80 percent pea-size pebbles).

A--0 to 3 inches; light brownish gray (10YR 6/2) extremely gravelly loamy coarse sand, dark grayish brown (10YR 4/2) moist; massive; soft, loose, nonsticky and nonplastic; few very fine and fine roots; common very fine interstitial pores; 65 percent pebbles; abrupt wavy boundary.

C--3 to 7 Inches; light brownish gray (10YR 6/2) extremely gravelly coarse sand, grayish brown (10YR 5/2) moist; single grained; loose, loose, nonsticky

and nonplastic; few fine and medium roots; few very fine interstitial pores; 70 percent pebbles; abrupt wavy boundary.

2Cr--7 to 25 inches; light gray (10YR 7/2) granitic grus; can be excavated by hand with difficulty.

3R--25 inches; hard, slightly fractured granite.

Remarks: Depth to paralithic contact varies from 4 to 20 inches.

Typic Cryumbrepts, loamy-skeletal, mixed

This soil family consists of moderately deep to granitic rock, well drained soils that formed in residuum and colluvium weathered from granitic rock sources. They occur on glacial basin floors. Slopes range from 5 to 35 percent.

Typically they have dark surface layers overlying a brighter chroma subsoil. The subsoil rests upon granitic rock.

Following is a profile description of a representative pedon (88-2K-13) found in the map unit *50 Lithic Cryumbrepts - Jointed granitic outcrop - Typic Cryumbrepts complex, 15 to 35 percent slopes*. It is located in the Volcanic Lakes area about 1 mile southeast of Lake of the Fallen Moon on the Marion Peak 15' quadrangle. Elevation is approximately 9500 feet.

Oi--0.5 to 0 inches; slightly decomposed conifer needles, twigs and cones.

A1--0 to 3 inches; very dark gray (10YR 3/1) extremely boundary coarse sandy loam, very dark brown (10YR 2/2) moist; moderate fine granular structure; soft, very friable, nonsticky and nonplastic; many very

fine and fine roots; common very fine and interstitial pores; 25 percent pebbles, 10 percent cobbles, 20 percent stones, and 20 percent boulders; abrupt wavy boundary.

A2--3 to 8 inches; dark brown (10YR 3/3) very cobbly sandy loam, very dark grayish brown (10YR 3/2) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine interstitial pores; 15 percent pebbles and 20 percent cobbles; abrupt wavy boundary.

Bw1--8 to 15 inches; dark yellowish brown (10YR 3/4) very cobbly sandy loam, dark brown (10YR 3/3) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine and medium roots; common very fine and fine interstitial pores; 15 percent pebbles and 30 percent cobbles; clear wavy boundary.

Bw2--15 to 21 inches; light yellowish brown (10YR 6/4) very cobbly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine and medium roots; common very fine and fine interstitial pores; 25 percent pebbles and 30 percent cobbles; abrupt wavy boundary.

2C--21 to 28 inches; dark yellowish brown (10YR 4/6) very gravelly loamy sand, dark yellowish brown (10YR 3/6) moist; single grained; loose, loose, nonsticky and nonplastic; few fine and medium

roots; 25 percent pebbles and 15 percent cobbles;
abrupt smooth boundary.

2R--28 inches; hard, granitic rock.

Remarks: The soil temperature taken at 20 inches on 7/6/88 was 49°F.

Typic Xerumbrepts, loamy-skeletal, mixed, frigid

This soil family consists of moderately deep to rock, somewhat excessively drained soils that formed in colluvium and morainal material weathered from granitic rocks. They occur on canyon sideslopes. Slopes range from 15 to 75 percent slopes.

Typically they have a dark surface layer overlying a lighter colored, higher chroma subsoil. The subsoil, in turn, rests on granitic rock.

Following is a profile description of a representative pedon (88-2K-25) found in the map unit 60 *Lithic Xerumbrepts - Lithic Mollic Haploxeralfs - Typic Xerumbrepts complex*, 45 to 75 percent slopes. It is located 1.5 miles northeast of Windy Peak on the northwest-facing slopes of Windy Ridge on the Marion Peak 15' quadrangle. Elevation is approximately 8000 feet.

Oi--2 to 0 inches; slightly decomposed conifer needles,
bark and twigs, and manzanita leaves.

A1--0 to 3 inches; dark grayish brown (10YR 4/2) very
gravelly fine sandy loam, very dark brown (10YR
2/2) moist; weak medium subangular blocky parting
to moderate very fine granular structure; soft,
very friable, nonsticky and nonplastic; many very
fine and common fine and medium roots; common very

fine interstitial pores; 40 percent pebbles, 5 percent cobbles, and 10 percent stones; clear wavy boundary.

A2--3 to 8 inches; brown (10YR 5/3) very gravelly fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine and medium roots; common very fine and fine interstitial pores; 30 percent pebbles, 10 percent cobbles, and 5 percent stones; clear wavy boundary.

Bw--8 to 21 inches; pale brown (10YR 6/3) very cobbly fine sandy loam, dark yellowish brown (10YR 4/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine and few medium and coarse roots; common very fine and fine tubular pores; 20 percent pebbles, 15 percent cobbles, and 5 percent stones; abrupt wavy boundary.

2R--21 inches; hard, fractured granitic rock.

Remarks: The cambic horizon (Bw) generally has a little more clay than the A horizon but not quite enough for an argillic.

TABLE 3-KC

MAP UNIT LEGEND
DOUGHERTY PEAK STUDY AREA
Kings Canyon National Park

<u>SYMBOL</u>	<u>MAP UNIT NAME</u>
10	Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes.
21	Jointed granitic outcrop - Lithic Cryumbrepts complex, 10 to 25 percent slopes.
22	Jointed granitic outcrop - Lithic Cryumbrepts complex, 15 to 45 percent slopes.
23	Jointed granitic outcrop - Granitic talus - Lithic Cryumbrepts complex, 45 to 130 percent slopes.
24	Jointed granitic outcrop - Lithic Cryumbrepts complex, 45 to 130 percent slopes.
25	Jointed granitic outcrop - Granitic talus - Felsenmeer complex, 45 to 130 percent slopes.
26	Jointed granitic outcrop - Granitic talus - Felsenmeer complex, 15 to 75 percent slopes.
27	Jointed granitic outcrop - Granitic talus - Lithic Xerumbrepts complex, 60 to 130 percent slopes.
28	Jointed granitic outcrop - Lithic Cryumbrepts complex, 15 to 45 percent slopes.
29	Jointed dacitic outcrop - Lithic Xerumbrepts - Typic Xerumbrepts complex, 45 to 130 percent slopes.
40	Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes.
50	Lithic Cryumbrepts - Jointed granitic outcrop - Typic Cryumbrepts complex, 15 to 35 percent slopes.
51	Lithic Cryumbrepts - Jointed granitic outcrop - Typic Cryorthents complex, 30 to 75 percent slopes.
60	Lithic Xerumbrepts - Lithic Mollic Haploxerales - Typic Xerumbrepts complex, 45 to 75 percent slopes.

MAP UNIT LEGEND, Continued

<u>SYMBOL</u>	<u>MAP UNIT NAME</u>
61	Lithic Xerumbrepts - Typic Xerumbrepts - Jointed granitic outcrop complex, 15 to 50 percent slopes.
70	Typic Cryumbrepts - Humic Cryaquepts - Lithic Cryumbrepts complex, 5 to 30 percent slopes.
71	Typic Cryumbrepts - Lithic Cryumbrepts - Jointed granitic outcrop complex, 5 to 45 percent slopes.
80	Granitic talus - Jointed granitic outcrop - Lithic Xerumbrepts complex, 30 to 60 percent slopes.
81	Granitic talus - jointed granitic outcrop complex, 45 to 130 percent slopes.
90	Humic Cryaquepts - Typic Cryofluvents complex, 0 to 15 percent slopes.
100	Entic Xerumbrepts - Jointed granitic outcrop complex, 25 to 65 percent slopes.
110	Lithic Cryumbrepts - Lithic Xerorthents - Jointed granitic outcrop complex, 45 to 75 percent slopes.
W	Lakes and Other Water Bodies

MAP UNITS OF THE DOUGHERTY PEAK STUDY AREA

DESCRIPTIONS OF MAP UNITS

10 Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes.

This map unit occurs on unglaciated sideslopes and ridges. Slopes are complex. This unit is composed of two components.

- 50% Typic Cryorthents, sandy-skeletal, mixed, shallow;
15 to 45 percent slopes
- 30% Jointed granitic outcrop

The Typic Cryorthents are very shallow and shallow to grus, excessively drained soils that occur on dissected mountain sideslopes and ridges. Typically the soil surface is covered by 80 percent pebbles, mostly pea-size. The jointed granitic outcrop commonly has a very thin mantle of pea-size pebbles on its surface. It occurs mostly on the middle and upper parts of the unit on convex slopes and ridges.

Vegetative cover is scattered lodgepole pines with about 5 to 10 percent canopy cover with very little understory plants and plant litter.

There are two inclusions.

- 10% Lithic Cryorthents, sandy-skeletal, mixed; 15 to 45 percent slopes
- 10% Typic Cryumbrepts, loamy-skeletal, mixed; 15 to 35 percent slopes

Lithic Cryorthents occur around the jointed granitic outcrop and are very shallow to granitic bedrock. The Typic Cryumbrepts occur

in the lower, slightly concave mountain sideslopes and glacial basins. They are moderately deep to granitic rock.

21 Jointed granitic outcrop - Lithic Cryumbrepts complex, 10 to 25 percent slopes.

This map unit is on ground till overlying scoured glacial basins. Slopes are complex. The unit is composed of two components.

60% Jointed granitic outcrop.

30% Lithic Cryumbrepts, loamy-skeletal, mixed.

The Lithic Cryumbrepts are shallow, somewhat excessively drained soils that occur on undulating bottoms of scoured glacial basins. It occurs between rock joints and crevices. The surface is covered with 65 percent rock fragments, dominantly small pebbles.

Vegetative cover is lodgepole pine with 10 to 20 percent canopy cover. There are very few understory plants.

There are two inclusions in this map unit.

5% Typic Cryumbrepts, loamy-skeletal, mixed; 5 to 15 percent slopes.

5% Cryofluvents; 0 to 10 percent slopes.

Typic Cryumbrepts are moderately deep to bedrock, somewhat excessively drained soils that occur in lower sideslopes. The Cryofluvents occur around drainageways and seeps. They are deep and are poorly drained.

22 Jointed granitic outcrop - Lithic Cryumbrepts complex, 15 to 45 percent slopes.

This map unit occurs on glacial basins and cirques. Slopes are complex. The unit is composed of two components.

60% Jointed granitic outcrop.

30% Lithic cryumbrepts, loamy-skeletal, mixed; 15 to 45 percent slopes.

The Lithic Cryumbrepts are shallow, somewhat excessively drained soils that occur between rock joints and crevices on lower side-slopes of glacial basins and cirques. The soil surface is covered by about 80 percent rock fragments, dominantly pea-size pebbles.

Vegetative cover is dominantly lodgepole pine with smaller amounts of whitebark and white pines. The canopy cover is 5 to 15 percent. The small amount of understory plant existing are chinquapin, willow and sedges.

There is one inclusion in this map unit.

10% Typic Cryumbrepts, loamy-skeletal, mixed; 15 to 45 percent slopes.

These soils are moderately deep and occur in slightly concave lower sideslopes.

23 Jointed granitic outcrop - Granitic talus - Lithic Cryumbrepts complex, 45 to 130 percent slopes.

This soil map unit occurs on cirque basins. Slopes are complex. The unit is composed of three components.

- 60% Jointed granitic outcrop
- 20% Granitic talus
- 15% Lithic Cryumbrepts, loamy-skeletal, mixed, 45 to 75 percent slopes.

The Lithic Cryumbrepts are shallow, well drained soils that occur on sideslopes of cirque basins between rock joints and crevices. Vegetative cover is widely scattered whitebark and white pines with less than one percent understory plants.

There are two inclusions in this map unit.

- 4% Typic Cryumbrepts, loamy-skeletal, mixed; 15 to 45 percent slopes.
- 1% Cryofluvents; 0 to 10 percent slopes.

24 Jointed granitic outcrop - Lithic Cryumbrepts complex, 45 to 130 percent slopes.

This map unit is on sideslopes of cirque basins. Slopes are complex. The unit is composed of two components.

- 75% Jointed granitic outcrop.
- 20% Lithic Cryumbrepts, loamy-skeletal, mixed; 45 to 75 percent slopes.

The Lithic Cryumbrepts are shallow, somewhat excessively drained soils that occur on sideslopes of cirque basins between rock joints and crevices.

Vegetative cover is scattered whitebark and white pines with less than 5 percent canopy cover. A few shrubs include mount mahogany, currant and willows.

There are two inclusions in this map unit.

3% Granitic talus.

2% Felsenmeer.

25 Jointed granitic outcrop - Granitic talus - Felsenmeer complex,
45 to 130 percent slopes.

This map unit is on cirque headwalls and talus cones above tree-line. Slopes are complex. The unit is composed of three components.

55% Jointed granitic outcrop

20% Granitic talus

15% Felsenmeer

There are three inclusions in this map unit.

6% Typic Cryorthents, sandy-skeletal, mixed

3% Lithic Cryumbrepts

1% Cryaquepts

The Typic Cryorthents are moderately deep and deep, excessively drained soils that occur within the granitic talus. The Lithic Cryumbrepts are shallow and very shallow, excessively drained soils that occur around rock outcrop. The Cryaquepts are poorly drained soils around seeps and drainages.

26 Jointed granitic outcrop - Granitic talus - Felsenmeer complex,
15 to 75 percent slopes.

This map unit occurs on high cirque basins, unglaciated divides and glacial terraces above treeline. Slopes are complex. The unit is composed of three components.

55% Jointed granitic outcrop
20% Granitic talus
15% Felsenmeer

Glacial debris in the form of stones and boulders cover about a third of the jointed granitic outcrop surface.

There are two inclusions in this map unit.

5% Typic Cryorthents, sandy-skeletal, mixed
5% Lithic Cryumbrepts

The Typic Cryorthents occur in between the stones and boulders in the talus. The Lithic Cryumbrepts occur between the rock joints and crevices and on ledges.

27 Jointed granitic outcrop - Granitic talus - Lithic Xerumbrepts complex, 60 to 130 percent slopes.

This map unit occurs on glacial basins sidewalls and river canyon walls. Slopes are complex. The unit is composed of three components.

55% Jointed granitic outcrop
20% Granitic talus
15% Lithic Xerumbrepts, loamy-skeletal, mixed, mesic,
60 to 75 percent slopes

The Lithic Xerumbrepts are very shallow and shallow, somewhat excessively drained soils that occur in between rock joints and crevices and on rock ledges.

Vegetative cover is scattered Jeffrey pine, incense cedar and black oak with a canopy cover of less than 10 percent. Also there is about 5 percent low sagebrush and 10 percent manzanita coverage.

There are two inclusions in this map unit.

5% Lithic Xerumbrepts, loamy-skeletal, mixed, frigid

5% Typic Xerumbrepts, loamy-skeletal, mixed, frigid

The Lithic Xerumbrepts are very shallow and shallow, somewhat excessively drained soils that occur in the rock outcrop in the higher elevations. The Typic Xerumbrepts are moderately deep and deep, somewhat excessively drained soils that occur commonly on slightly concave sideslopes.

28 Jointed granitic outcrop - Lithic Cryumbrepts complex, 15 to 45 percent slopes.

This map unit occurs on glacial basins sideslopes. Slopes are complex. There are two components in this map unit.

60% Jointed granitic outcrop

30% Lithic cryumbrepts, loamy-skeletal, mixed; 15 to 45 percent slopes

This map unit is composed of bench-like patterns of rectangular blocks of jointed granitic outcrop orientated in a northeast direction. A block of rock alternates with soil in a series of steps. The Lithic Cryumbrepts are very shallow and shallow, somewhat excessively drained soils that occur between rock joints, crevices and on rock ledges.

Vegetative cover is mostly lodgepole pine, white pine and whitebark pine.

There are three inclusions in this map unit.

4% Lithic Cryorthents, sandy-skeletal, mixed

4% Typic Cryumbrepts, loamy-skeletal, mixed

2% Cryaquepts

The Lithic Cryorthents occur in the upper part of the unit. The Typic Cryumbrepts are moderately deep, somewhat excessively drained soils that occur on the lower and slightly concave sideslopes. The Cryaquepts are poorly drained soils around seeps and drainages.

29 Jointed dacitic outcrop - Lithic Xerumbrepts - Typic Xerumbrepts complex, 45 to 130 percent slopes.

This map unit occurs on canyon walls. Slopes are complex. The unit is composed of three components.

- 50% Jointed dacitic outcrop
- 35% Lithic Xerumbrepts, loamy-skeletal, mixed, mesic;
45 to 75 percent slopes
- 15% Entic Xerumbrepts, loamy-skeletal, mixed, mesic; 45
to 75 percent slopes

The Lithic Xerumbrepts are very shallow and shallow, somewhat excessively drained soils that occur on sideslopes of canyon walls in between rock joints, crevices and on rock ledges. The Entic Xerumbrepts are moderately deep and deep, somewhat excessively drained soils that occur on slightly concave lower sideslopes of canyons.

There are three inclusions in this map unit.

- 5% Lithic Xerumbrepts, loamy-skeletal, mixed, frigid;
45 to 75 percent slopes
- 5% Typic Xerumbrepts, loamy-skeletal, mixed, frigid;
45 to 75 percent Slopes
- 5% Dacitic talus

Both of these soils are similar to the mesic component soils. They have slightly cooler temperatures however.

40 Typic Cryorthents - Jointed granitic outcrop complex, 15 to 45 percent slopes.

This map unit is on scoured glacial basins. Slopes are complex. The unit is composed of three components.

- 45% Typic Cryorthents, sandy-skeletal, mixed; 15 to 45 percent slopes
- 25% Jointed granitic outcrop
- 20% Typic Cryorthents, sandy-skeletal, mixed, shallow; 15 to 45 percent slopes

The first component are moderately deep to granitic rock, excessively drained soils that occur in depressions. The third component are very shallow and shallow to granitic grus, excessively drained soils that occur in between rock joints and crevices and on rock ledges.

Vegetative cover is lodgepole pine with some whitebark pine and white pine. Canopy cover is 10 to 20 percent. Very few plants are in the understory.

There are two inclusions in this map unit.

- 5% Felsenmeer
- 5% Granitic talus

50 Lithic Cryumbrepts - Jointed granitic outcrop - Typic Cryumbrepts complex, 15 to 35 percent slopes.

This map unit is on glacial basin floors and lower sideslopes. Slopes are complex. The unit is composed of three components.

- 45% Lithic Cryumbrepts, loamy-skeletal, mixed; 15 to 35 percent slopes
- 35% Jointed granitic outcrop
- 15% Typic Cryumbrepts, loamy-skeletal, mixed; 15 to 35 percent slopes

The Lithic Cryumbrepts are very shallow and shallow, somewhat excessively drained soils that occur between rock joints and crevices and on rock ledges. The Typic Cryumbrepts are moderately deep, well drained soils that occur in depressions on glacial basin floors.

Vegetative cover is lodgepole, whitebark and foxtail pines. The canopy cover is 10 to 20 percent. The understory amounts to 10 to 20 percent.

There is one inclusion in this map unit.

- 5% Humic Cryaquepts, sandy-skeletal, mixed; 5 to 15 percent slopes

The Humic Cryaquepts are very poorly and poorly drained soils that support meadow vegetation.

51 Lithic Cryumbrepts - Jointed granitic outcrop - Typic Cryorthents complex, 30 to 75 percent slopes.

This map unit is on glaciated and unglaciated cirque walls, mountain ridges and sideslopes. Slopes are complex. The unit is composed of three components.

- 35% Lithic Cryumbrepts, loamy-skeletal, mixed; 45 to 75 percent slopes
- 30% Jointed granitic outcrop

20% Typic Cryorthents, sandy-skeletal, mixed; 30 to 45 percent slopes

The Lithic Cryumbrepts are very shallow and shallow, somewhat excessively drained soils that occur on ridges and on the upper mountain sideslopes. The Typic Cryorthents are mostly moderately deep, excessively drained soils that occur on the lower mountain sideslopes associated with talus.

Vegetative cover is whitebark pine and white pine in the higher and cooler sites and lodgepole pine in the lower and warmer sites. There is very little understory plants.

There are two inclusions in this map unit.

12% Granitic talus

3% Felsenmeer

60 Lithic Xerumbrepts - Lithic Mollic Haploxeralfs - Typic Xerumbrepts complex, 45 to 75 percent slopes.

This map unit is on canyon sideslopes. Slopes are complex and are unstable with many loose rock fragments on the surface. The unit is composed of three components.

30% Lithic Xerumbrepts, loamy-skeletal, mixed, frigid;
45 to 75 percent slopes

25% Lithic Mollic Haploxeralfs, loamy-skeletal, mixed,
frigid; 45 to 75 percent slopes

25% Typic Xerumbrepts, loamy-skeletal, mixed, frigid;
45 to 75 percent slopes

The Lithic Xerumbrepts are mostly shallow, somewhat excessively drained soils that occur on rocky crests and ridges. The Lithic Mollic Haploxeralfs are mostly shallow, somewhat excessively

drained soils that occur on canyon sideslopes around rock outcrops. The Typic Xerumbrepts are moderately deep, somewhat excessively drained soils that occur on smooth to slightly convex canyon sideslopes.

Vegetative cover is mostly manzanita, canyon liveoak and ceanothus on the first component. The second component has low sagebrush, phlox and Idaho fescue on it. The third has mostly manzanita and ceanothus with a few scattered Jeffrey and sugar pines and western juniper. This area has been subjected to a repeated number of burnings.

There are two inclusions in this map unit.

14% Jointed granitic outcrop

6% Entic Cryumbrepts; 30 to 60 percent slopes

The Entic Cryumbrepts are on north and east aspects often in slightly concave pockets. The vegetation includes willows, snowberry and western white fir.

61 Lithic Xerumbrepts - Typic Xerumbrepts - Jointed granitic outcrop complex, 15 to 50 percent slopes.

This map unit is on canyon and glacial basins sideslopes. Slopes are complex. The unit is composed of three components.

40% Lithic Xerumbrepts, loamy-skeletal, mixed, frigid;
15 to 50 percent slopes

35% Typic Xerumbrepts, loamy-skeletal, mixed, frigid;
15 to 50 percent slopes

20% Jointed granitic outcrop

The Lithic Xerumbrepts are shallow, somewhat excessively drained soils that occur in between rock joints and crevices around rock

outcrops. The Typic Xerumbrepts are moderately deep and deep, somewhat excessively drained soils that occur on canyon sideslopes.

Vegetative cover is mainly manzanita, ceanothus and low sagebrush on the Lithic Xerumbrepts. Jeffrey pine with some white fir with an understory of similar shrubs occurs on the Typic Xerumbrepts.

There are two inclusions in this map unit.

- 7% Entic Xerumbrepts, sandy-skeletal, mixed, frigid;
30 to 60 percent slopes
- 3% Aquents

The Entic Xerumbrepts are moderately deep and deep, excessively drained soils that occur in sheltered, commonly north and east facing lower sideslopes. They support red fir. The Aquents are poorly drained soils that occur around seeps and drainages.

70 Typic Cryumbrepts - Humic Cryaquepts - Lithic Cryumbrepts
complex 5 to 30 percent slopes.

This map unit is on undulating glacial basin floors. Slopes are complex. The unit is composed of three components.

- 35% Typic Cryumbrepts, loamy-skeletal, mixed; 5 to 15
percent slopes
- 25% Humic Cryaquepts, sandy-skeletal, mixed; 5 to 15
percent slopes
- 25% Lithic Cryumbrepts, loamy-skeletal, mixed; 15 to 30
percent slopes

The Typic Cryumbrepts are moderately deep, well drained soils that occur on gently rolling glacial basin floors. The Humic Cryaquepts are deep, very poorly and poorly drained soils that occur around seeps and drainageways. The Lithic Cryumbrepts are shallow,

somewhat excessively drained soils that occur on short sideslopes. It has about 60 percent rock fragments on the surface of which 15 to 40 percent are stones and boulders.

Vegetative cover is mainly lodgepole pine and lesser amounts of white pine on the first and third components. Subalpine vegetation including willow, sedges, mountain heather and some lodgepole pine occur on the second component.

There are two inclusions in this map unit.

- 13% Jointed granitic outcrop
- 2% Rubbleland (glacial)

71 Typic Cryumbrepts - Lithic Cryumbrepts - Jointed granitic outcrop complex, 5 to 45 percent slopes.

This map unit is on glacial basins and lower mountain sideslopes. Slopes are complex. The unit is composed of three components.

- 45% Typic Cryumbrepts, loamy-skeletal, mixed; 5 to 15 percent slopes
- 30% Lithic Cryumbrepts, loamy-skeletal, mixed; 15 to 45 percent slopes
- 15% Jointed granitic outcrop

The Typic Cryumbrepts are moderately deep to granitic rock, well drained soils that occur on the glacial basin floors. The Lithic Cryumbrepts are very shallow and shallow, somewhat excessively drained soils that occur on mountain sideslopes associated with rock outcrop.

Vegetative cover is mainly lodgepole pine with lesser amounts of western white pine and whitebark pine. There are very few understory associates.

There are two inclusions in this map unit.

5% Cryaquepts

5% Rubbleland (glacial)

The Cryaquepts are very poorly and poorly drained soils that support meadow vegetation.

80 Granitic talus - Jointed granitic outcrop - Lithic Xerumbrepts complex, 30 to 60 percent slopes.

This map unit is on canyon sideslopes and alluvial fans. Slopes are complex. The unit is composed of three components.

55% Granitic talus

20% Jointed granitic outcrop

15% Lithic Xerumbrepts, loamy-skeletal, mixed, frigid;
30 to 60 percent slopes

The Lithic Xerumbrepts are very shallow and shallow soils to granitic rock, somewhat excessively drained soils that occur on glacial basins, rocky crests, and ridges of canyons.

Vegetative cover is mainly shrubs such as ceanothus, manzanita, willow, choke cherry, and canyon liveoak. Trees cover less than 5 percent of the unit.

There is one inclusion in this map unit.

10% Entic Xerumbrepts, loamy-skeletal, mixed, mesic

The inclusion are moderately deep and deep, somewhat excessively drained soils that occur on the lower sideslopes.

81 Granitic talus - Jointed granitic outcrop complex, 45 to 130 percent slopes.

This map unit is on cirque head walls, avalanche chutes and ridges. Slopes are complex. The unit is composed of two components.

- 45% Granitic talus
- 40% Jointed granitic outcrop

There is three inclusions in this map unit.

- 7% Cryaquepts, 15 to 75 percent slopes
- 5% Lithic Cryumbrepts, loamy-skeletal, mixed; 50 to 75 percent slopes
- 3% Typic Cryorthents, sandy-skeletal, mixed; 50 to 75 percent slopes

The Cryaquepts are very poorly drained and are covered by sedges, grasses, and some willows. The Lithic Cryumbrepts are very shallow and shallow to granitic rock, well drained soils. The Typic Cryorthents are moderately deep and deep, excessively drained soils that occur between the talus.

90 Humic Cryaquepts - Typic Cryofluvents complex, 0 to 15 percent slopes.

This map unit is on drainageways and stream outwash deposits and around seeps. The unit is composed of three components.

- 40% Humic Cryaquepts, sandy-skeletal, mixed; 0 to 5 percent slopes
- 25% Typic Cryofluvents, sandy, mixed; 0 to 10 percent slopes
- 20% Humic Cryaquepts, sandy-skeletal, mixed; 5 to 15 percent slopes

The first component are deep, very poorly drained soils that occur in drainageways. The second component are deep, moderately well drained soils that occur on the stream outwash deposits. The third component are deep, somewhat poorly and poorly drained soils that occur in drainageways and around seeps.

Vegetative cover is wet and dry meadow vegetation such as sedges, cinquefoil, buttercup, currant and willows on the first and third component soils. The second component has large lodgepole pines with very little understory.

There are three inclusions in this map unit.

8% Lithic Cryumbrepts, loamy-skeletal, mixed; 5 to 20 percent slopes

6% Typic Cryumbrepts, loamy-skeletal, mixed; 5 to 20 percent slopes

1% Surface water

100 Entic Xerumbrepts - Jointed granitic outcrop complex, 25 to 65 percent slopes.

This map unit is on canyon sideslopes. Slopes are complex. The unit is composed of two components.

50% Entic Xerumbrepts, loamy-skeletal, mixed, mesic; 25 to 45 percent slopes

30% Jointed granitic outcrop

The Entic Xerumbrepts are moderately deep, somewhat excessively drained soils that occur on the lower and warmer canyon sideslopes.

Vegetative cover is Jeffrey pine, black oak, incense cedar and canyon live oak.

There are three inclusions in this map unit.

- 10% Entic Xerumbrepts, sandy-skeletal, mixed, frigid;
45 to 65 percent slopes
- 7% Lithic Xerumbrepts, loamy-skeletal, mixed, mesic
- 3% Granitic talus

The Entic Xerumbrepts are moderately deep and deep, somewhat excessively drained soils that occur on the upper and cooler sideslopes. The vegetation is mainly red fir with some sugar pine and Jeffrey pine. The Lithic Xerumbrepts are very shallow and shallow, somewhat excessively drained soils that occur around jointed granitic outcrop.

110 Lithic Cryumbrepts - Lithic Xerorthents - Jointed granitic outcrop complex, 45 to 75 percent slopes.

This map unit is on unglaciated canyon sideslopes. Slopes are complex. The unit is composed of three components.

- 35% Lithic Cryumbrepts, sandy-skeletal, mixed; 45 to 75 percent slopes
- 35% Lithic Xerorthents, sandy-skeletal, mixed, frigid;
45 to 75 percent slopes
- 20% Jointed granitic outcrop

The Lithic Cryumbrepts are very shallow and shallow to granitic rock, excessively drained soils that commonly occur on the north and east aspects. The Lithic Xerorthents are very shallow and shallow to granitic rock, excessively drained soils that commonly occur on the west and south aspects.

Vegetative cover is red fir, western white pine and lodgepole pine with 20 to 40 percent canopy cover on the Lithic Cryumbrepts.

Jeffrey pine, sugar pine and a small amount of red fir cover the Lithic Xerorthents. Cover is about 5 to 15 percent. There is one inclusion in this map unit.

5% Entic Xerumbrepts, sandy-skeletal, mixed; 45 to 75 percent slopes

This inclusion are moderately deep and deep, somewhat excessively drained soils that are on the lower northerly aspects.

W Lakes and Other Water Bodies.